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PROGRAM IN INFORMATION POLICY

ENGINEERING-ECONOMIC SYSTEMS DEPARTMENT

STANFORD UNIVERSITY • STANFORD, CALIFORNIA 94305

VOLUME I

RESEARCH IN SPACE COMMERCIALIZATION, TECHNOLOGY TRANSFER, AND COMMUNICATIONS

Final Report

for the Period

July 1, 1978 - June 30, 1983

NASA Contract NASW 3204

Principal Investigators

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PROGRAM IN INFORMATION POLICY

Engineering-Economic Systems Department
Stanford University   Stanford, California 94305

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PART I: EXECUTIVE SUMMARY

This is the Final Report under NASA Contract NASW 3204, a program of research and internships in national space policy with special reference to (a) technology transfer, (b) communications policy, and (c) the commercialization of space.

Program Summary

Program Objectives

The first objective of this program was to make available to NASA and the Senate, as interns, a group of Ph.D. candidates trained in the application of quantitative analytical techniques to policy issues. The second objective of the program was to conduct a research program in national space policy, with special reference to (a) technology transfer, (b) communications policy, and (c) the commercialization of space. Research resulting from the program provided both specific and long-term policy perspectives to NASA and the Senate.

Program Activities

This program had two coordinated activities for fulfilling the program objectives: (1) the provision of Ph.D. candidates in the Engineering-Economic Systems Department as interns at either NASA Headquarters or the Senate Committee on Commerce, Science and Transportation (the "off-campus" program); and (2) the conduct of research by EES students and faculty at Stanford University (the "on-campus" program). The off-campus program was initiated in July, 1978. The on-campus program was initiated in October of the same year.

As preparation for the internship, students participated as research assistants in on-going research of policy concern to NASA or the Senate Committee. The program also provided post-internship support for students pursuing Ph.D. research within the program's subject areas. During the five year period from July 1, 1978 to June 30, 1983, a total of 15 students and 5 professors contributed to the on-campus research effort, and 11 students participated in internships ranging in duration from one to two years. Exhibit 1 lists the personnel involved in the project. The research conducted under the program resulted in the preparation of numerous exploratory and discussion papers, 22 of which were completed as research reports and are included in this Final Report.

Report Summary

This Final Report is a collection of 22 reports that relate to national space policy. The research procedure was first to prepare working papers which were discussed with interns and individuals at Stanford, NASA and the Senate Subcommittee Staff, and then to prepare reports of the type incorporated in this final report. Sometimes working papers initiated by interns were expanded into fuller reports after the student returned to Stanford. Not included in this report are (a) the numerous exploratory and discussion papers concerning research topics which were not pursued and (b) those documents, such as position papers, which were prepared for purposes other than research.

The papers included in this report examine issues related to three national space policy topics: (1) technology transfer, (2) communications policy, and (3) commercialization of space. Parts II - IV of this report

Exhibit 1: Cumulative List of Program Participants

Faculty

Donald A. Dunn, Professor

Carson E. Agnew, Assistant Professor

John T. McAlister, Adjunct Professor

D. Warner North, Consulting Professor

Edward G. Cazalet, Consulting Professor

Students*

Murray R. Metcalfe

Frederick E. Dopfel

Ralph D. Samuelson

J. Lindsay Bower

Richard Chee, Jr. (Senate Committee on Commerce, Science and Transportation)

Mark J. Matousek (Senate Committee on Commerce, Science and Transportation)

Matthew R. Willard (NASA Headquarters)

Robert D. Stibolt (NASA Headquarters)

Franklin G. Neubauer (NASA Headquarters)

Steven Glass (NASA Headquarters)

Peter Matlock (NASA Headquarters)

Thomas Lehmann (NASA Headquarters)

David Cariño (NASA Headquarters)

Michael Simon (NASA Headquarters)

Dean Olmstead (NASA Headquarters)

* Internship shown in parentheses.

contain papers dealing with each of these topics. The following sections of the Executive Summary contain synopses of the papers addressing these topics. The numbering plan of these sections parallels the numbering of the body of the final report.

PART II: TECHNOLOGY TRANSFER

Research related to technology transfer was conducted in four main areas: (a) General issues, (b) NASA technology transfer, (c) Market-oriented approaches to national science policy, and (d) Markets with implications for technology transfer policies. The papers associated with each of these topics are briefly described below.

A. General Issues

The overall goal of any R&D project funded by the public sector is to produce social benefits which exceed the costs of the program. It is often the case that the social benefits can only be achieved if the results of the research programs are transformed into commercial ventures. The paper "Evaluating the Benefits of Public Sector R&D Projects: Accounting for Technology Transfer" **addresses some general issues regarding this technology transfer process. It develops a specific economic model of the process to enable an analysis of the effects of various policy options on the technology transfer process.**

B. NASA Technology Transfer

The papers in this section address several issues which were of special interest to NASA's Technology Transfer Office.

1. Government Patent Policy and the Transfer Process

Clearly, the **commercialization of inventions resulting from** government-sponsored research is affected by the patent system. The paper

"Government Patent Policy" addresses the role of government patent policies on the technology transfer process. The paper was prepared during the debate over the "Stevenson Bill" which (as enacted) substantially changed the federal governments policy on patents which resulted from federally sponsored research. Three alternative patent government policies are examined and efforts to reform the system are described.

2. A Technology Transfer Case Study (COSMIC)

The Computer Software Management and Information Center (COSMIC) was maintained by NASA as a clearinghouse for computer programs developed by NASA and the Defense Department. COSMIC's role thus provided an opportunity to conduct a case study of technology transfer. Under COSMIC, the market for software that developed during the course of NASA and DOD research is analyzed. Because the cost of buying software from COSMIC usually is only a small part of the life-cycle cost of using the program, pricing of COSMIC software is not a critical issue. Customer or user uncertainty regarding the exact capabilities of the government-developed software is found to be a possible impediment to the transfer of the technology. This uncertainty (a market imperfection) affects to varying degrees the adoption and use of all new technology. Options for improving this aspect of the technology transfer process are considered in the papers in the next two sections.

3. A Team Approach to Screening

The paper "Improving NASA's Technology Transfer Process through Increased Screening and Evaluation in the Information Dissemination

Program' in this section proposes a government/industry team approach to screening and evaluation of NASA-generated technologies. The objective of this approach is to determine the commercial feasibility of a wide range of technical applications. It is argued that such pre-screening reduces user costs and uncertainties but may prevent the ultimate user from exercising his own judgement and making the most effective use of the available information.

4. Use of NASA/RECON Files for Technology Transfer

An alternative method for improving the flow of information between industry and NASA, which maintains high user involvement but with low user cost, is the use of machine readable data bases. Such data bases are discussed in "A Survey of Machine Readable Data Bases," and the use of NASA's RECON files is proposed as an instrument of technology transfer.

5. Adoption Lags in NASA R&D

The research described in this section was conducted in order to provide insight into duration of and the reasons for the lag which occurs between the start of NASA-sponsored research and the development of new technology. Because similar studies have been conducted of the private sector lag, another objective of the research was to compare the public and private lags. The causes of this gestation period need to be understood to determine which, if any, policies would be effective in shortening the lag. The lag was measured using patent and patent waiver data maintained by NASA.

C. Market-Oriented Approaches to National Science Policy

The two papers in this section address the approaches to technology transfer that might supplement the information service approach which NASA has taken thus far. "Organizational Options for the Transfer of Space Technology to Commercial Markets" discusses a proposal to establish a quasi-governmental research and development corporation. Several other organizational alternatives are also analyzed. The second paper in this section, "The Economic Basis for National Space Policy" takes an even broader view and examines the possibilities for increased use of market-oriented approaches to implementing a national science and technology policy. This shift away from reliance on direct public action can provide benefits to society in the form of an increased rate of innovation and of more "appropriate" technology, better suited to the needs of consumers.

D. Markets, With Implications for Technology Transfer Policies

There are two papers in the section on extraordinary market considerations. "An Inquiry into the Household Economy" is a detailed study of a specific question that arose during the study of national science and technology policy: Just how important is the household economy in comparison with the market economy? Most science and technology policy studies have concentrated on growth in GNP and on productivity in the market economy. This study indicates that the household economy is comparable to the market economy in size and importance. This result raises questions about the validity of policy studies that do not take the growth and productivity of the household economy into account.

The second paper, "Legal Restraints Confronting Domestic U.S. Firms in Their Foreign Operations" deals with issues arising in regard to United States laws and regulations which apply to domestic firms doing business abroad. It is observed that U.S. industries which might be expected to expand their sales in international markets would probably be very technological in nature. This paper implies the need for further study of the impacts which such complex incentives and restrictions faced by multinational enterprises may have on the rate and direction of technological change within the U.S.

PART III: COMMUNICATIONS POLICY

Within the communications policy area, research was conducted in four areas: (A) spectrum management, (B) models for evaluating communications systems, (C) the communications regulatory environment, and (D) expert predictions and consensus. The related papers are described below.

A. Spectrum Management

As a major user of the radio-frequency spectrum, NASA has a continuing interest in efficient spectrum use. Moreover, NASA's communications program supports research dedicated to enhancing technologies which alleviate spectrum "congestion." Three papers were prepared during the program, each of which examined a particular radio service and used economic analysis to analyze methods of promoting efficient use.

1. Economic Approaches to Orbit-Spectrum Management

The problems associated with the allocation of a scarce resource--the radio frequency spectrum used by geostationary communications satellites --are presented in the first paper. It is observed that users of the spectrum have little or no incentive for improving and conserving their use of the resource because they are not required to pay the full social cost of their spectrum use. Economic criteria by which the effectiveness of various resource allocation mechanisms can be judged are developed. Some thoughts are presented on traditional objections to using market-oriented mechanisms for allocating the spectrum resource.

2. Frequency Coordination and Spectrum Economics

This section reports on an existing technique of spectrum management: "frequency coordination." Although engineers tend to regard frequency coordination as a purely technical activity, it is shown that coordination (as practiced in the 4-6 GHz band) has the properties of a market in spectrum. In fact, frequency coordination institutionalizes an implicit economic market, with attendant property rights, and thus promotes economically as well as technically efficient use of the spectrum.

3. Licensing Arrangements and Spectrum Economics: The Case of MDS

The third paper on spectrum management examines several alternative mechanisms to comparative hearings for the assignment of radio licenses. The FCC has proposed these methods in several radio services, including Multi-point Distribution Service, which is used as an example. The analysis suggests that the present system of holding comparative hearings whenever mutually conflicting license applications are filed is a costly way to select amongst applicants. Calculations indicate that auctions and lotteries with resale of the license are both more efficient than hearings but that lotteries are not as good as auctions.

B. Models for Evaluating Communication Systems

Several papers were prepared which use engineering-economic techniques to analyze communications problems. This section contains three papers, each covering a separate area.

1. Selecting Alternative Satellite Technologies

"An Illustrative Analysis of Technological Alternatives for Satellite Communications" develops a decision analysis model for choosing among alternative satellite technologies, explicitly taking into consideration the efficient use of the spectrum resource. The analytic methodologies developed are applied to the examination of satellite R&D decisions such as those faced by NASA.

2. Least Cost Local Distribution of Satellite Signals

The research on this topic leads to a model for selecting the least cost local distribution system for satellite signals, a subject that strongly affects overall satellite system design. The results indicate that the least cost arrangement is one with a central earth station with cable access in regions with high to medium traffic densities, combined with individual earth stations or (for higher volumes) radio access for remote users.

3. The Cost of Local Rural Telephone Service

A study of investment costs of serving a rural telephone subscriber in the U.S. is presented in this section. Existing regulations have led to the subsidization of rural service which may have suppressed innovation in rural telephony by keeping the apparent cost of service below its true cost. New technologies, such as NASA's proposed rural mobile communication service, may in fact have a lower true cost than the existing service. Although a number of advanced technologies exist for providing telephone service to rural communities, no such technologies have been

implemented in the U.S. except experimentally. However, as long as the cost of the new technology is above the subsidized cost, innovation is unlikely to occur.

The paper examines a number of engineering cost studies, and estimates a statistical cost function using data from the Rural Electrification Administration. Surprisingly, it finds that the cost of a local loop and terminal equipment (including a share of central office terminal costs) is probably under $1000 per main station. However, the range of values is very large (from under $250 to over $1000).

C. The Communications Regulatory Environment

The communications regulatory environment is described in this section and the report presents some of the implications which changes in the environment may have for NASA. The report reviews the recent legislative, judicial and regulatory events which affect the industry. Several recommendations are made which will enable NASA to maintain its effectiveness in light of these changes.

D. Expert Prediction and Consensus

Research on how to use multiple assessments of uncertain variables by multiple experts is described here. The work on expert assessment led to the development of a procedure for calibrating certain experts' assessments. This research was conducted because expert predictions of future events are a fundamental requirement in policy making. For instance, the NASA Communications Program relied on forecast of the demand for orbit-spectrum as partial justification for its 20/30 GHz research program.

PART IV: SPACE COMMERCIALIZATION

Two of the most promising areas for private sector involvement in the exploitation of space are remote sensing and manned space stations. The papers in this section address the possibilities for private investment and suggest policies which will expedite commercialization.

A. Remote Sensing

The extent of the market for Landsat products and ground processing equipment is one of the most important and least understood parameters facing potential commercial operators of an earth remote sensing system. The first paper on remote sensing, "Understanding the Landsat Market in Developing Countries," describes the Landsat market in developing countries and the constraints on the growth of that market which stem from the development process itself and from a country's technical, political and institutional attributes. The second paper, "Landsat: Historical Overview and Political Analysis," is an extension of the first and undertakes a political systems analysis.

B. Manned Space Operations

The possibility of private financing and operation of the Space Operations Center (SOC) was considered by NASA to be an alternative to SOC development by the government. In this section's first paper, "Financial Assessment of the Space Operations Center as a Private Business Venture," a revenue model is constructed and compared with NASA cost estimates. A present value analysis is performed and shows a potential for substantial

profit in a private SOC venture, although the possibility of large losses also exists. The second paper, "Private Financing of a Space Station," broadens the scope of the study to consider the overall attractiveness of manned space stations operations from a business perspective. The most significant problems faced by a private company involved in any space station enterprises are outlined, and possible government policies to overcome these difficulties are suggested. This analysis is relevant to NASA's interest in including the private sector in the commercialization of a manned presence in space.

Report Organization

Each of the papers in this volume is preceded by an abstract providing more information about its contents. The abstract also indicates the author(s) of the original paper. For easier reference, the abstract is labeled according to the outline scheme used above, i.e., II.A, II.B.1, and so forth. For case of handling, the report comprises two volumes. Volume I contains Parts I (Executive Summary), and Part II (Technology Transfer). Volume II contains Parts III (Communications Policy) and IV (Space Commercialization).

EVALUATING THE BENEFITS OF PUBLIC SECTOR R&D PROJECTS: ACCOUNTING FOR TECHNOLOGY TRANSFER

Murray R. Metcalfe
July 1979

Abstract

The overall goal of any R&D project funded by the public sector should be to produce social benefits which exceed the cost of the project. However, it is often the case that the social benefits can only be achieved if the results of the research programs are transformed into commercial ventures by private firms. This process is referred to as technology transfer.

The first section of this paper addresses some general issues regarding technology transfer and suggests some approaches to modeling the technology transfer process. Then a specific economic model of the process is developed. The model considers all of the major processes involved in the transfer of R&D results from the public to the private sector. It explicitly considers the decision-making process of the individual firm.

The effects of various policy options on the technology transfer process are analyzed in the final section of the paper. The model of technology transfer process developed earlier is used in the analysis. The policy areas include taxation policies, subsidies, patent life, and the encouragement of cross-licensing.

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Evaluating the Benefits of Public Sector R&D Projects: Accounting for Technology Transfer

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July, 1979

Preface

This paper consolidates three earlier papers by the author: "Public Sector R&D Project Selection: Accounting for Technology Transfer," March 1979; "Evaluating the Benefits of Public Sector R&D Projects: Accounting for Technology Transfer," May 1979; and "Technology Transfer: Modeling the Impact of Selected Policy Options," June 1979.

1. Introduction

The overall goal of any R&D project funded by the public sector is to produce social benefits which exceed the cost of the project. It is often the case that the social benefits can only be achieved if the results of the research programs are transformed into commercial ventures by private firms. This process is referred to as technology transfer.

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2. A Framework for Examining the Technology Transfer Process

2.1. Major Feature of the Process

It is not generally the case that producing technologies for transfer to the private sector is the primary goal of a government agency. For example, the primary goal of DOD is providing national defense, while the primary goal of NASA is space exploration and development. For the purposes of this research, however, we will focus on those program areas for which aiding in the development of commercial ventures that are in the public interest is a primary goal.

Government funding of research and its adoption by private sector firms must yield net perceived benefits to both parties if it is to be undertaken. To the government, one form of these benefits may be the increase in social surplus (i.e. consumer surplus plus producer surplus) due to the project and subsequent adoption, minus the program costs. This criteria holds for any government R&D project and in general for any government project of any type. The benefits as perceived by the firm will be in terms of profit, return on investment, and other financial objectives. The firm will consider many factors in determining the profit or return on investment potential of a new venture. These factors include exposure (required investment), cash flows, time horizons, interest rates, and risk. Different decision-makers in the private sector may use different decision criteria (see Greenberg, 1977). Executives of large corporations may make their decisions mainly on the basis of discounted cash flows. Venture capitalists,

concerned with new businesses, may be more interested in maximum exposure, the first profitable year, and payback period. In all cases, potential sources of funds and interest rates will be of major importance.

A government agency selecting R&D programs must first establish that the programs will yield net social benefits. Conventional benefit-cost analysis techniques which consider consumer and social surplus are applicable. However, the level of benefits produced will clearly depend on the private sector reaction to the research project. The private sector will only adopt the technology resulting from the project if the opportunity for commercialization appears to satisfy the firm's financial criteria. Thus the government agency must anticipate the private sector reaction to the research results in making its project selection decision. It is this feature of the problem which makes R&D decision-making particularly difficult when technology transfer is involved. The development of a model that predicts private sector reaction is discussed in later sections of this paper.

So far nothing has been said about uncertainty. Uncertainty prevades all of the processes mentioned above. There is uncertainty over the results of any research project. The probability of the project reaching its technological goals is a factor in the decision-making process. The private sector will carefully consider the risk involved in the commerciali-zation process. And further, the government agency is uncertain

about the private sector response to research results; i.e. how eager will the private sector be to adopt the resulting technology. Any decision-making framework developed must explicitly deal with the uncertainties inherent in the problem.

Below we discuss the key elements of a framework to describe the technology transfer process. Before discussing the development of a framework and the key models, a slight diversion will be made to answer an important question at this point: why should the government perform research leading to technology transfer? As well as justifying public sector R&D, the answer to this question provides some interesting insights which will be useful in the modeling process.

2.2 Government R&D: Justification

There are three major reasons to support government funding of R&D activities (Leland, 1977). A discussion of each follows.

(1) Imperfect Markets

Economic theory indicates that in a competitive market economy, operating without government intervention, the market will allocate resources in an efficient manner. This includes an allocation to risky ventures such as R&D, since unregulated capital markets are available to spread risk.

In reality, market distortions are pervasive. These include: monopolies and cartels, taxes, regulation mechanisms such as price controls and subsidies, public goods, etc. Allocations to risky ventures are particularly hindered by distortions. A complete set of markets for sharing risk does not exist. Also, capital markets are heavily regulated. The

total effect of such distortions is to interfere with the efficient allocation of resources. Economic theory shows that a common tendency of the distortions listed above is to cause underinvestment. In the case of R&D, this means that level of R&D being carried out falls below the socially efficient level. Public sector R&D may then be justified on the grounds that it increases the overall amount of R&D being performed and thus increases social welfare.

(2) R&D Produces Information

The output of R&D is information. For example, one can think of R&D as the production of information pertaining to the costs of achieving technological objectives. The information may state how an objective can be met at a lower cost. The R&D process may also produce information which reduces the uncertainty associated with costs. An interesting insight here is that an R&D project may provide information (and therefore have value) even if it is "unsuccessful". The project may still indicate new directions to be taken in research in the future.

Information is known to be a difficult quantity to deal with in an economic framework. Information is a public good: it can be used by many parties at the same time. A private firm which produces information through R&D may end up sharing information with other firms, leading to lower returns from the information. This leads to underinvestment since the firm cannot capture the full value of the information produced. Patents are an attempt to convert information from a public to a private good. However, patents will lead in many cases

to market distortions and social inefficiency. Patents may lead to information being withheld or to the creation of monopolies.

Government funding of R&D makes the information produced widely available. Thus it corrects for underinvestment, and at the same time avoids the creation of market distortions.

(3) Divergence of Social and Private Risk Attitude

An argument put forward by Arrow and Lind states that the government has a very large portfolio of projects, and therefore should behave in a risk neutral manner. Managers of private firms on the other hand behave in a risk averse manner. Thus the private sector may reject projects as too risky that have a positive expected value, and therefore would be undertaken by the government. In other words the social value of the research exceeds the private value, and is sufficiently high to justify the project.

Even if the Arrow-Lind argument is left aside, the difference in discount rates encountered in the public and the private sectors indicates that the government may accept projects the private sector would reject. The government's lower discount rate allows it to underwrite projects which are considered too risky by the private sector.

Although the above factors may justify government involvement in R&D, the government should not fund R&D when sufficient incentive faces the private sector to induce private firms to undertake the project. It may however be the case that while the private sector will undertake the research, governmental research is required as a supplement to raise the overall amount of research to a level which is socially efficient.

2.3 Approaches to Modeling the Technology Transfer Process

It is possible to think of the technology transfer process in terms of three sub-processes. Below these sub-processes are identified, and possible approaches to modeling them are discussed.

(1) The Technological Process

The first process to be examined is the production of research results during the research project. Several models for this process have appeared in the literature (Abernathy, 1970; Marschak, 1967; Nelson, 1961). In many cases the resulting cost of the technology is taken as the outcome variable, and uncertainty about the cost is stated as a probability distribution.

There are several aspects of the technological process which could be examined in some detail. The first is the "time-cost" tradeoff: by increasing project funding, the time required to complete the research is reduced. This introduces the question of timing into the model. Another area of interest is the interaction between research projects. It is often assumed in the literature that projects are indepen-

dent; i.e. the results of one project are not influenced by the results of other projects being carried out. This assumption is clearly invalid, and a model which included the interactions between projects would be desirable.

The fact that the output of the technological process is information suggests the decision analysis concept of "value of information" might be applicable. But there is a feature of the R&D situation which makes this approach particularly interesting. In a decision analysis framework, it is assumed the decision-maker can buy information which will assist him in making his decision. This will be true in the R&D selection decision. The agency can buy information which will aid in making the project selection decision. But in the decision analysis paradigm information of this type generally is of no further value to the decision-maker once the decision has been made. However, this is not true in the R&D case. One way the agency can purchase information on the decision is simply to let the R&D project begin and progress. That is, information is being purchased which will be useful after the decision has been made. This idea was touched upon by the RAND Corporation research on parallel R&D strategies carried out in the early 1960's (Nelson, 1961). This concept will be explored in more detail.

(2) The Firm's Implementation Decision

If public sector R&D is to yield net social benefits in a technology transfer environment, it is necessary the research results be commercialized by a private firm. Thus

the likelihood that the research result will be implemented is crucial to determining project viability. It is therefore necessary to explicitly model the process by which firms evaluate candidate commercialization prospects.

As a first step, it is necessary to establish which financial criteria are most important to the evaluation process. Many studies have simply used the discounted cash flow of the commercialization venture. It is also necessary to examine the firm's risk attitude, and to model the effects of risk aversion on the decision process.

Given a model of the decision-making process of private sector firms, it is then necessary to examine how the results of the government R&D enter into the evaluation of the commercialization venture. The output of this model will be a measure of the likelihood that the private sector will develop the research result. One such measure is the "probability of adoption" for the technology being developed (see Greenberg, 1977).

(3) Benefit Estimation by the Public Sector

In order to be considered for inclusion in the government R&D portfolio, a program must yield net social benefits after transfer and commercialization. The estimation of benefits in the technology transfer case is simpler than benefit evaluation for the more general government R&D situation. If we assume the resulting commercial product enters the competitive marketplace at a price dictated by supply and

demand, then the problem of determining "intangible" benefits is largely avoided. This is in contrast to the situation where the R&D is performed for say military or space exploration purposes, where the benefits do not accrue in the marketplace. If the resulting technology enters a competitive market, social benefits can be calculated based on the change in consumer surplus and producer surplus.

The benefit estimation process can be viewed as the framework in which all of the other models operate. Both the technological process model and the model of the firm's implementation decision are inputs to the benefit estimation process. The estimated social benefits of the R&D, when considered with the program costs, allow the prioritization of candidate R&D projects.

In the following section a specific model of the technology transfer process is developed.

3. A Model of the Technology Transfer Process

The model provides a framework for the calculation of the net social benefit of a government research program when technology transfer is involved. In the previous section, the three major components of such a framework were discussed. They were the technological process, the transfer process (or the firm's implementation decision), and the benefit estimation (or market impact) process. The model presented here includes each of those components, but concentrates on the transfer process. The model explicitly considers the decision-making process of an individual firm when confronted with a risky venture.

3.1 Overview of the Model

It is assumed that the research results are of interest to all of the firms in one and only one market or industry. It is assumed that the market is competitive, and is at a long run equilibrium before the research takes place. It is assumed there are no competing innovations currently available to the industry.

The model divides the technology transfer process into three distinct time periods. Benefits and costs accrue through each phase. The overall net benefits are then determined by aggregating over the three phases with an appropriate social discount rate. The phases are:

i) Phase I (time period T_o through T_1)--the research is carried out by the government agency, at a cost C.

ii) Phase II (time period T_1 through T_2)--firms examine and evaluate the results of the research; some firms develop and implement the results, with some means of appropriating the benefits of their development efforts.

iii) Phase III (time period T_2 through T_3)--the developments of the research results from Phase II diffuse to firms not originally involved in the development efforts, leading to a new market equilibrium and resulting benefits in terms of consumer surplus.

The models for each phase of the process are described below. However, we first examine the original market setting, before the research takes place.

3.2 The Market Setting Before Innovation

It is assumed the industry is made up of n firms, which are identical, except as detailed below. The long-run market equilibrium before any innovation is described in Fig. 3-1. The demand curve ABC is linear and does not change with time. The long-run supply curve is horizontal at the price p_o, and each firm produces a quantity q_o. Since the market has reached a long-run equilibrium, the number of firms will be such that the profit accruing to each firm is zero. Since profits are zero, the total social surplus is represented by consumer surplus, which is represented by the area ABD in the diagram.

For ease of mathematical manipulation, it is assumed that the cost function of each firm is quadratic, and is given by:

$$TC(q) = aq^2 + b \qquad a > 0, b > 0$$

If each firm has the same cost function, the average cost will equal the marginal cost at production quantity q_o in a long-run equilibrium, and both will equal the market price p_o.

3.3 Phase I--The Research Process

During Phase I the research project is carried out by the government agency. During that time, it is assumed the market continues to operate at the original equilibrium.

As stated in the previous section, many models of the research process appear in the literature. For the purposes of this

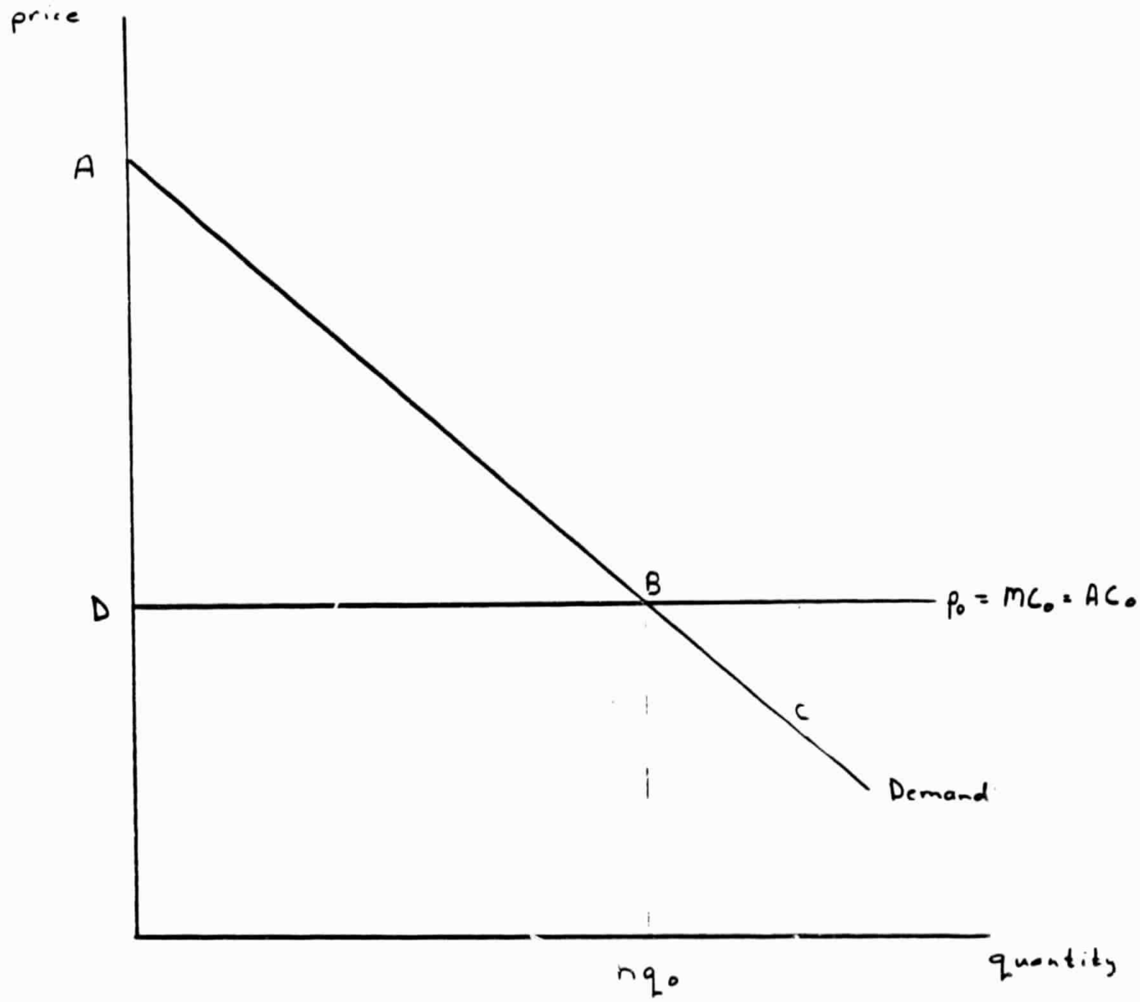


Fig. 3-1. The Market Before Innovation

research, we have not explicitly modeled the process, but have instead adopted a simple description of the output of the process, as described below. Further, we have assumed all research projects are independent (i.e. the success or failure of one project does not affect the outcome of other projects).

The output of the research project is information; the information produced may take on many forms. In an applied research or development project, the information may relate to some particular aspect of a production process. We will be more general and assume only that the output is information which is potentially useful to the industry and can be summarized by the information state Z.

The resulting information state Z will be revealed at the end of Phase I, at time T_1, and will be available to the firms before their implementation decisions are made. However, for the purposes of the evaluation of the project benefits, which is presumably being carried out before Phase I begins, Z is not known with certainty. The uncertainty can be described by the probability distribution $\{Z\}$ on Z. Since Z is uncertain, all the assessments made in evaluating Phases II and III will be conditional on Z. This conditionality will be temporarily suppressed for notational convenience, but will be re-introduced before the final benefit calculation is made.

Finally, the government incurs a cost for conducting the research. We let the total cost be C, and assume it is incurred at time T_o.

3.3 Phase II--The Transfer Process

Phase II takes place from time T_1, to time T_2. At T_1 the result of the government research project, Z, is made available to the industry. (Patent and license issues are discussed below).

It is assumed the eventual use of the research results will be to improve the production process of the industry. In some cases the results of the research will be immediately applicable to the production process, with no further development required. More often however, it will be necessary for a firm wishing to use the results to undertake development efforts to make the results applicable to its production process. The level of success of the development process is itself an uncertainty, and therefore implementation of the innovation presents a risk to the firm. Each firm will evaluate the risks involved and made a decision on whether to implement the innovation.

The process by which firms make implementation decisions in reality is often complex and varies widely from firm to firm. In constructing this model, four factors affecting the decision-making process of the firm have been considered:

- the financial criteria employed by the firm
- the risk attitude of the firm's management
- the firm's cost of capital
- the firm's ability to appropriate the benefits of its development efforts

For the purpose of the model, profit will be used as the sole financial criterion on which decisions were made. An expanded and more complex version of the model might also include cash flows, indebtedness, etc.

Risk attitude will be incorporated by assuming each firm makes decisions based on the "certain equivalent" of profits as determined by applying an exponential utility function to the firm's profit flow. Risk attitude will be the only attribute which is assumed to vary between the firms in the industry. The variation will be in represented terms of the risk aversion coefficient of the firm's utility function. It will be assumed all of the firms are risk averse.

The cost of capital, which will appear as the discount factor used by the firms, will be taken to be the same for each firm in the industry. An extended version of the model could allow for different costs of capital for different firms.

Finally, the firm's decision-making is influenced by its ability to appropriate the benefits of its development efforts. To begin, and as a slight aside we assume the government charges no royalty fees for the use of its innovations (assuming they have been patented), and also does not grant exclusive licenses. Both of these actions appear to be consistent with maximizing social welfare. It can be shown royalty fees lead to a deadweight loss to the consumer (see Nordhaus, 1967). Exclusive licenses can lead to monopolistic behavior. However it should be noted in reality there may be

justification for both government royalty fees and exclusive licenses. Royalty fees allow the agency to recoup expenses directly which may be valuable to the agency politically. Exclusive licenses may act as a further encouragement to implementation by the private sector for particularly risky ventures.

Despite the fact it cannot obtain an exclusive license to the use of the basic innovation, a firm in general can appropriate at least some of the benefits of development. First it may be able to develop the basic idea to a point where the firm itself can apply for a patent. Even if it cannot obtain a patent, a firm may be able to protect its ideas by keeping them secret, or by simply by being the first to introduce them and thus increase its share of the market. In any case, the competitive advantage afforded by successful development will eventually vanish as the idea diffuses to the other firms in the industry.

The model developed here assumes that each firm undertaking development does so independently, and can maintain exclusive rights to the use of its resulting production processes throughout Phase II. It is further assumed that any firm undertaking development is constrained to use the resulting process, even if it turns out to be inferior to the original industry-wide process. Thus the firms undertaking development may make positive or negative profits, depending on the success of their development efforts. No other firm can adopt the firm's

process until the beginning of Phase III. At the beginning of Phase III all exclusive rights vanish, and the entire industry moves to the best production process developed during Phase II. Thus in Phase III the market will move to a new zero-profit equilibrium.

We now make a series of assumptions which allow us to look at the implementation decision quantitatively. First, it is assumed that each firm is constrained to continue producing the quantity q_o throughout Phase II, regardless of whether its profits are positive, zero or negative. Therefore the total quantity supplied in Phase II is unchanged, and the market price remains at p_o.[1]

Secondly, it is assumed that all benefits and costs due to development are reflected only in the parameter a of the firms' cost function. Firms not undertaking development continue to experience the parameter value a_o. Firms undertaking development each move independently to a new value of a, which may be either less than or greater than a_o. The probability distributions on the final value of a for each firm undertaking development are assumed to be identical, and have a normal distribution:

$$\{a\} \sim \text{Normal}(\bar{a}, \sigma^2)$$

where $\bar{a} = ka_o \qquad 0 < k < 1$

Each firm i undertaking development can be considered to select a value a_i from the distribution on a, and is constrained to

1 The removal of this assumption greatly complicates the analysis, as does assuming firms will leave the market if the profits are negative. Formulations of this type are being developed by the author.

retain that value throughout Phase II. Firms not implementing retain the parameter a_o and continue to make profits of zero. On the other hand, for firm i which does undertake development, the instantaneous profit rate is:

$$\pi_i(t) = \text{Revenue} - TC\ (q_o)$$
$$= p_o q_o - a_i q_o^2 - b$$

Since in the zero profit case:

$$p_o q_o - a_o q_o^2 - b = 0$$

we have:

$$\pi_i(t) = (a_o - a_i)\ q_o^2 \tag{1}$$

We note that $\pi_i(t)$ can be either positive or negative, depending on the value of a_i.

The firm will make its implementation decision on the basis of the present value of profits over the length of Phase II.

$$\pi_i = \int_{T_1}^{T_2} \pi_i(t) e^{-rt} dt$$

where r is the cost of capital to the industry. Substituting (1) into the above we have:

$$\pi_i = \int_{T_1}^{T_2} (a_o - a_i)\ q_o^2\ e^{-rt}\ dt$$

$$= \frac{q_o^2}{r}(a_o - a_i)(e^{-rT_1} - e^{-rT_2}) \tag{2}$$

Since a_i has a normal distribution, π_i also has a normal distribution:

$$\{\pi_i\} \sim \text{Normal}\left[\frac{q_o^2}{r}(a_o - \bar{a})(e^{-rT_1} - e^{-rT_2}),\ \frac{q_o^4}{r^2}(e^{-rT_1} - e^{-rT_2})^2 \sigma^2\right] \tag{3}$$

The decision by firm i of whether to implement will be based on a comparison of the uncertain profits described by $\{\pi_i\}$ if it implements, to the certain profits of zero if it does not. The decision will depend on the firm's risk

attitude. If we assume firm i has risk aversion coefficient γ_i in its exponential utility function, we can compare its certain equivalent on profits if it implements to a certain equivalent of zero if it does not. For a normal distribution, the certain equivalent for an exponential utility function can be described by a closed form expression (Howard, 1977). Thus:

$$CE(\pi_i) = \frac{q_o^2}{r}(a_o - \bar{a})(e^{-rT_1} - e^{-rT_2}) - \frac{1}{2}\gamma_i \frac{q_o^4}{r^2}(e^{-rT_1} - e^{-rT_2})^2 \sigma^2 \quad (4)$$

The firm will implement if:

$$CE(\pi_i) > CE(0) = 0 \quad (5)$$

or, using (4) and (5)

$$\gamma_i < \frac{2r(a_o - \bar{a})}{q_o^2 \sigma^2 (e^{-rT_1} - e^{-rT_2})} \quad (6)$$

Given a firm's risk aversion coefficient γ_i, we can use (6) to determine whether the firm will implement the innovation. Generally, the firms within an industry will exhibit a range of risk attitudes, and thus different values of γ_i. As a simple example, if the distribution of risk aversion coefficients in the industry is described by Figure 4.2, one can determine the fraction of firms in the industry that will implement. If m is the number of firms that implement, the fraction implementing is:

$$\frac{m}{n} = \frac{1}{\gamma_u - \gamma_L}\left[\frac{2r(a_o - \bar{a})}{q_o^2 \sigma^2 (e^{-rT_1} - e^{-rT_2})} - \gamma_L\right] \quad (7)$$

where again n is the number of firms in the industry.

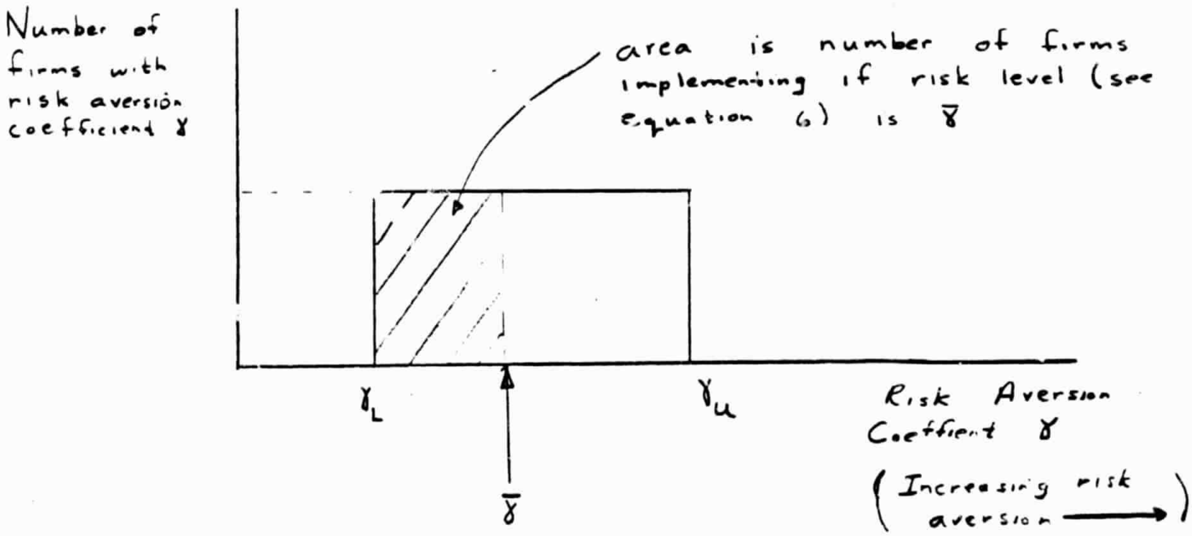


Fig. 4.2 The Range of Risk Attitudes for the Firms in the Market

We first note that if the right hand side of equation (6) is less than γ_L , then no firms undertake development. This means that the government research will have no effect on the industry. If technology transfer was the sole objective of the research program, the evaluation of the project will yield a net loss equal to the cost of the project.

Assuming now that the right hand side of (6) falls between γ_L and γ_W equation (7) can be examined to ensure it behaves as expected. First, we note that if $\bar{a}$, the expected value of a_i for the implementing firms, decreases, indicating even greater production improvements are expected, the fraction of firms implementing increases. If on the other hand the variance σ^2 of a_i increases, indicating there is more uncertainty in the development process, the fraction of firms implementing decreases.

An increase in T_2, indicating the length of Phase II has increased, leads to a decrease in the fraction of firms implementing. This result seems incorrect at first glance, and may in fact be due to peculiarity of the model. One would expect that as the time period over which the firm has exclusive rights to its new production process is increased, more firms would develop the innovation. The result derived from (7) is due to the fact that the model constrains firms which implement to continue to produce with cost parameter a_i, even if the value

of a_i exceeds a_o. Thus the possibility of an increase in cumulative net losses as V increases more than offsets the possible increases in cumulative profits, since the firms are all risk-averse.[2]

The effect of a change in r, the cost of capital, is difficult to determine directly from (7). It is also not directly evident what the result should be. In reality, a higher cost of capital would tend to reduce implementation if borrowing was involved. Within the confines of the model however, the effect of an increase in r is unclear. This matter will be examined in more detail in the near future.

Finally, the effect of γ_u can be noted. An increase in γ_u indicates an increase in the average risk aversion of the industry, leading as expected to a reduction in the number of firms implementing.

We can now calculate the overall benefit level in Phase II. Since the market price has not changed during Phase II, consumer surplus has not changed; the change in social surplus is equal to the total profits during Phase II. For simplicity we will assume a social utility function which allows us to work with expected values. Since firms not undertaking development accrued zero profits, we need only consider the m firms which undertook development.

$$\Delta SS = E\left(\sum_{i=1}^{m} \pi_i\right)$$

$$= \sum_{i=1}^{m} E(\pi_i)$$

2 This problem could be eliminated by formulating a fourth phase of the model, which would occur between Phase II and III. The new phase would be the same as Phase II, except each firm has the option of returning to the cost parameter a_o if a_i exceeds a_o for that firm. This additional feature is included in the form of the model used in Section 4.

We note risk aversion does not enter into this calculation. Therefore all firms implementing have the same expected value of profits in Phase II. For the calculation of social surplus, the industry cost of the capital r is replaced by the social discount rate s. Therefore:

$$\Delta SS = m E(\pi_i)$$
$$= m \frac{q_o^2}{s}(a_o - \bar{a})(e^{-sT_1} - e^{-sT_2}) \qquad (8)$$

3.4 Phase III--The Market Impact

Phase III takes place over the time period T_2 to T_3. At time T_2, it is assumed all rights to production process information developed by individual firms during Phase II disappear. All available information diffuses instantaneously to all firms in the industry, and to firms considering entry into the industry. Since all the information generated in Phase II related to lowering the cost parameter a, the lowest value of a discovered in Phase II, which we will label a_m, becomes known to all firms. We assume all firms move to the use of this parameter immediately and costlessly.

The probability distribution on a_m can be determined at the time of evaluation from the distribution $\{a_i\}$ on the parameter a_i. The distribution on a_m is derived as the distribution on the minimum value of a_i taken on by the m firms implementing the technology. For purpose of this paper, we will

not use an analytic expression for the distribution on a_m, but instead we will describe it simply as:

$$\{ a_m \mid m \}$$

where the conditionality denotes that the distribution depends on m, the number of firms implementing. We further assume that

$$\frac{\partial}{\partial m} E(a_m \mid m) < 0$$

that is, the mean of the distribution on a_m decreases as m increases. This means that if more firms decide to implement in Phase II, the resulting cost function of the industry in Phase III will be lower for any value of q.

The industry cost function in Phase III is therefore:

$$TC(q) = a_m q^2 + b$$

If in the long-run firms can enter and leave the market, profits will once again be driven to the zero level, but at a new equilibrium production quantity q_1. The new quantity q_1 will be the level at which the average cost of production:

$$AC(q) = a_m q + \frac{b}{q}$$

is minimized. That is:

$$\frac{\partial AC(q)}{\partial q} = a_m - \frac{b}{q^2} = 0$$

so

$$q_1 = \left(\frac{b}{a_m}\right)^{1/2}$$

is the optimal production quantity in Phase III.

At quantity q_1, the new average cost, AC_1, will be:

$$AC_1 = a_m q_1 + \frac{b}{q_1}$$

$$= 2\ (a_m b)^{\frac{1}{2}} \tag{9}$$

The probability distribution of AC_1 can be derived as a transformation of the distribution on a_m (see Howard, 1977). Again we represent the resulting distribution simply as:

$$\left\{AC_1 \mid m\right\}$$

noting the distribution depends explicitly on m. We expect

$$\frac{\partial}{\partial m} E(AC_1 \mid m) < 0$$

Thus as the number of firms implementing increases, the average cost can be expected to decline. Since the average cost equals market price, price also declines.

Since profits to individual firms return to zero in Phase II, the net change in social surplus will be the increase in consumer surplus due to the reduction of the market price. The expected value of the one-period increase in consumer surplus is shown in Fig. 3-3. Discounting at the social discount rate s, the expected value of the change in social surplus in Phase III can be calculated. Letting D(p) describe the demand at price p, it is:

$$\Delta SS = \int_{T_2}^{T_3} \Big\{ \left[AC_0 - E(AC_1/m) \right] q_0 + \frac{1}{2} \left[AC_0 - E(AC_1/m) \right] \left[D\left(E(AC_1/m)\right) - q_0 \right] \Big\} e^{-st}\, dt \tag{10}$$

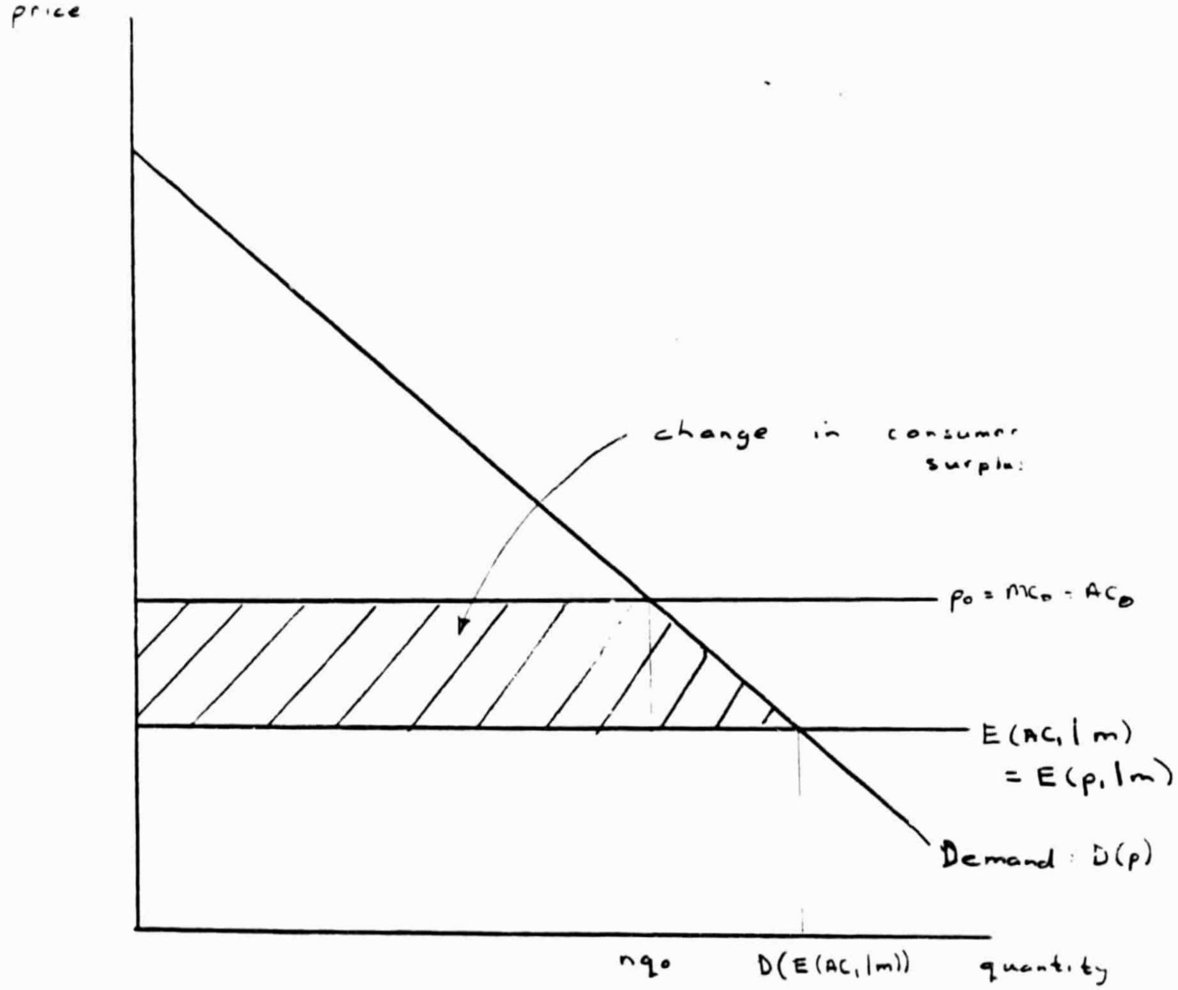


Fig. 3-3. Change in Consumer Surplus

3.5 Overall Calculation of Net Benefits

The total net benefits from the government R&D project can be determined simply by summing the net benefits over the three phases. That is, we sum over equations (8) and (10) and subtract the cost of the project C incurred at time T_0. The total charge in social surplus is:

$$\begin{aligned}\Delta SS = & m \frac{q_0^2}{s}(a_0 - \bar{a})(e^{-sT_1} - e^{-sT_2}) \\ & + \int_{T_2}^{T_3} \{ [AC_0 - E(AC_1|m)] q_0 \\ & \quad + \tfrac{1}{2}[AC_0 - E(AC_1|m)][D(E(AC_1|m)) - q_0]\} e^{-st} dt \\ & - (1+s)^{-T_0} C \end{aligned} \tag{11}$$

However, as was stated initially, all of the probability assessments made in Phases II and III were based implicitly on a specific research outcome Z occurring at T_1. To make this explicit, we rewrite the left-hand side of equation (11) as:

$$\Delta SS(z)$$

Therefore, the overall net social benefits should be calculated by weighting the outcome of equation (11) for each value of Z by use of the probability distribution on Z. Therefore:

$$\Delta SS = \int_{\text{all } z} \Delta SS(z) \{z\} \, dz \tag{12}$$

4. Modeling the Impact of Selected Policy Options

4.1 Introduction

This section uses the model developed above to analyze the impact of various policy options on technology transfer. The model will be used to determine the level of development and commercialization that will occur under a given policy, in terms of the fraction of the firms in a given industry that will undertake development of a specific research result.

It should be noted that an increase in innovative activity is only an intermediate measure of benefit. The social benefits of increased innovation occur in many forms, including increased consumer and producer benefits in domestic markets, international competitiveness of products and the improvement of balance of payments, productivity improvements, etc. Although it is possible to use the model to measure at least the first of these factors, the increase in the level of innovation due to a policy will be used as the measure of benefits.

For purposes of analytic tractability, an example is developed from the model, and is used to perform the analysis. Because the form used is only an example, and the data is illustrative, the main result is to demonstrate the model's ability to describe technology transfer, and its potential usefulness as a policy analysis tool.

Seven policy areas are analyzed. They are:

i) adjustment of corporate taxation policies

ii) subsidies

iii) direct government funding of development

iv) capital market regulation

v) patent life

vi) government provision of development assistance

vii) encouragement of cross licensing.

4.2 A Specific Form of the Model

For purposes of analytic tractability, an example has been developed from the model presented earlier for use in this section. The main change is that the example uses a discrete distribution on the cost parameter, rather than a continuous distribution. The simpler form of the example has made it possible to make several improvements in the model

Figure 4-1 depicts the development decision of a specific firm. Given development, three possible values of the cost parameter a_i could result: $k_1 a_o$, a_o, and $k_3\ a_o$, where a_o is the current value of the parameter a_i, and :

$$k_1 > 1 \quad ; \quad 0 < k_3 < 1$$

The three possibilities correspond to, respectively, an unsuccessful development effort, an effort that causes no change from the status quo, and a successful effort. The corresponding probabilities esitimates are p_1, p_2, and p_3.

Previously, it was assumed in the model that if a firm undertook development, it was constrained to the resulting value of a_i throughout Phase II. Thus even if the new parameter was higher than the old one, leading to negative profits, the firm could not return to the old process. Here it is assumed instead that the firm is constrained only to produce at the new parameter from time T_1 (the beginning of Phase II) to an intermediate point, time T_2. At time T_2, the firm may revert to the original parameter a_o if it is more profitable to do so. The firm then continues to produce until the end of Phase II, at time T_3. We will refer to T_2 as the development time, and T_3 as the patent life; i.e., the time during which the firm has exclusive rights to the development.[3]

The profit rates for each outcome are shown on the right side of Figure 4-1. The profit rate is calculated from a_i as:

$$\pi_i(t) = (a_o - a_i) q_o^2$$

For convenience we let $a_o q_o^2$ equal one.

The additional variables shown in Figure 1 are defined as follows:

T = corporate tax rate; note it applies only to firms with positive profits

S = rate of general subsidies (e.g., tax write-offs) to unsuccessful firms; i.e., firms with negative profits

3 Note that T_2 and T_3 as used in this section do not correspond to T_2 and T_3 in Section 3. The author apoligizes for this inconsistency.

K = level of direct government funding of development; applies regardless of the development outcome, and is paid at end of Phase II.

The future value of the profit stream for each outcome is shown on the far right of Figure 4-1. The discount rates r_1 and r_2 are used to distinguish between the cost of capital for borrowing and for lending or reinvestment.

The utility function for firm i is taken to have the form:

$$u(x) = -e^{-\gamma_i x}$$

where γ_i is the firm's risk aversion coefficient. The certain equivalent for the "develop" and the "not develop" alternatives can then be computed. For "not develop":

$$CE_{ND} = -e^{0} = -1$$

For the "develop" alternative:

$$CE_D = -p_1 e^{-\gamma_i[(1-k_1)(1-S)F_1 + K]} - p_2 e^{-\gamma_i K} - p_3 e^{-\gamma_i[(1-k_3)(1-T)F_2 + K]} \quad (13)$$

where:

$$F_1 = \int_{T_1}^{T_2} e^{r_1 t}\,dt$$

$$F_2 = \int_{T_1}^{T_3} e^{r_2 t}\,dt$$

The firm will decide to develop if:

$$CE_D > CE_{ND}$$

or,

$$p_1 e^{-\gamma_i[(1-k_1)(1-S)F_1 + K]} + p_2 e^{-\gamma_i K} + p_3 e^{-\gamma_i[(1-k_3)(1-T)F_2 + K]} < 1 \quad (14)$$

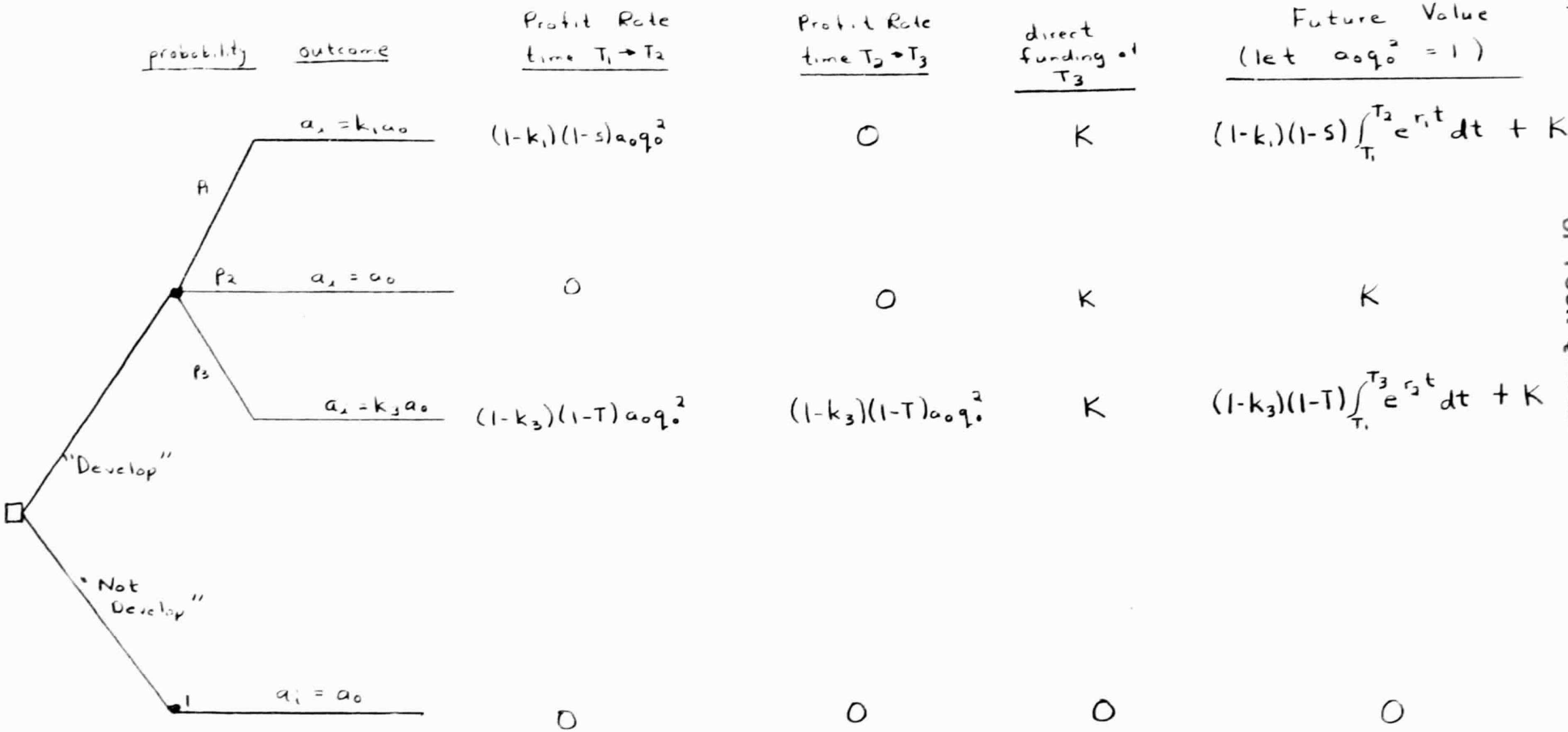


Fig. 4-1. The Firm's Development Decision

We define a maximum risk aversion coefficient γ_m, which is the largest value γ_i can take on and satisfy equation (14). Firms having a value γ_i below γ_m will choose to develop; firms with a value γ_i above γ_m are more risk averse and will decide against developing.

It will be assumed that the distribution of risk aversion coefficients in the industry is as described in Figure 4-2. Given γ_m, one can then determine f, the fraction of firms in the industry that will implement. If γ_m lies to the left of γ_L, f will equal zero; all of the firms are too risk averse to undertake development. If γ_m lies to the right of γ_u, all firms will undertake development. Finally we have:

$$f = \frac{\gamma_m - \gamma_L}{\gamma_u - \gamma_L} \qquad \text{if} \quad \gamma_L \leq \gamma_m \leq \gamma_u \qquad (15)$$

Unfortunately, a closed form expression for γ_m cannot be developed from equation (14). Equation (14) can, however, be solved numerically for γ_m. The lack of a closed form expression hampers the level of analysis that can be performed. Rather than making comparative statics analyses of the policy variables, hypothetical data will be used so that sensitivity analyses can be performed. These should provide a considerable amount of insight into the behavior of the model with respect to the policy options. However, since the data is hypothetical, the results are intended for illustrative purposes only.

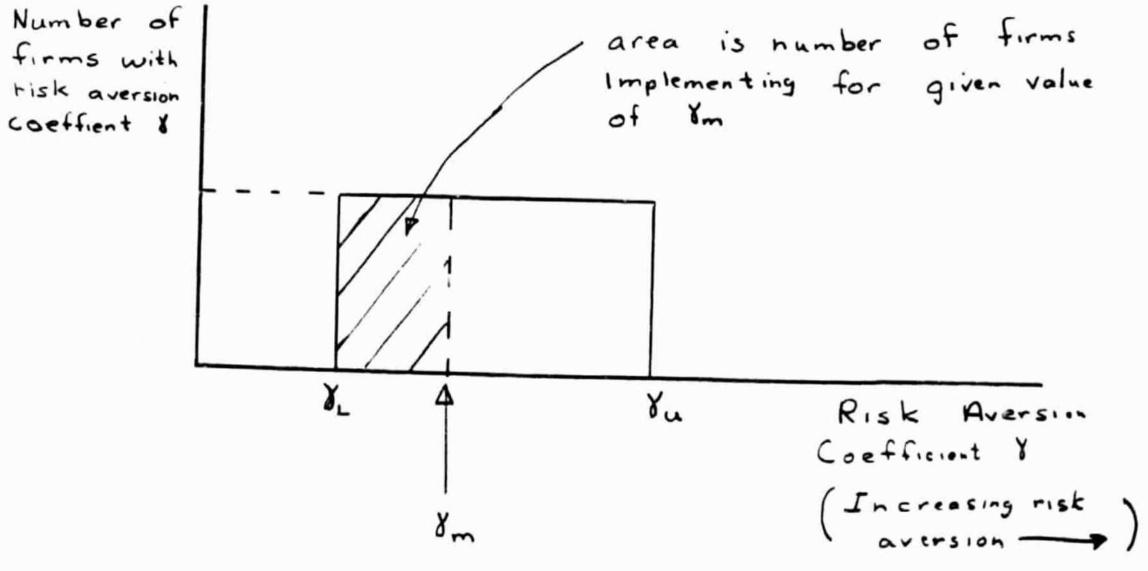


Fig. 4-2. The Range of Risk Aversion Coefficients for the Firms in the Industry.

4.3 Analysis of Policy Areas

The model, in the form specified in the last section, can be used to analyze the effect of a range of policy options. In this section, seven policy areas are examined. They are:

- corporate taxation policies
- subsidies
- direct funding of development
- capital rate regulation
- patent life
- provision of development assistance
- encouragement of cross licensing.

This list in no way represents all of the policy options available; there are many others (see Holloman et al., 1979). Also, we have not considered any of the many combinations of the above options, although these could easily be analyzed with the present form of the model.

In each policy area, the effect of policy will be measured in terms of its impact on γ_m, the maximum risk aversion coefficient, and f, the fraction of firms in the industry which undertake development.

Before examining the policy areas, a "base case" must be constructed.

a) Base Case

The first step is to select data for a base case. The values assigned to the model parameters are shown in Figure 4-3.

Fig. 4.3.Base Case Data

Development Decision

$k_1 = \frac{3}{2}$

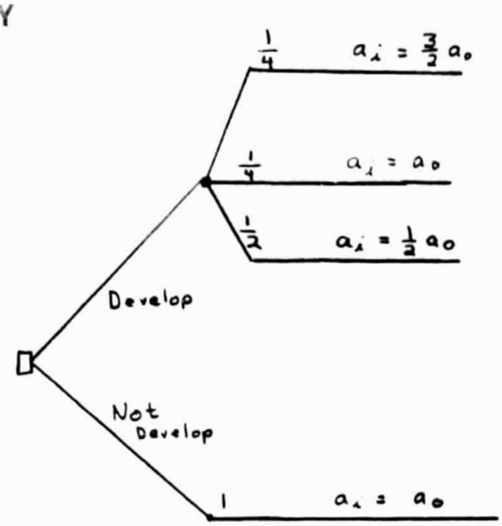
$k_3 = \frac{1}{2}$

$p_1 = \frac{1}{4}$

$p_2 = \frac{1}{4}$

$p_3 = \frac{1}{2}$

$\Longrightarrow$



Policy Variables

$T_1 = 0$

$T_2 = 3$

$T_3 = 6$

$r_1 = .2$

$r_2 = .1$

$T = .48$

$S = .50$

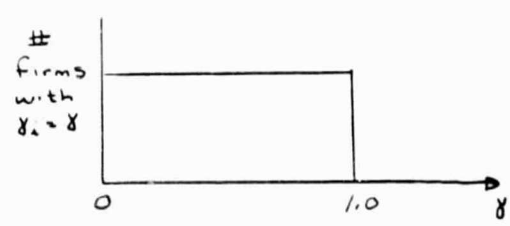
$K = 0$

Distribution of Risk Aversion Coefficients

$\gamma_L = 0$

$\gamma_u = 1.0$

$\Longrightarrow$



Using this data, equation (14) is solved for γ_m, yielding:

$$\gamma_m = .493$$

Thus a firm with a risk aversion coefficient γ_i below .493 would elect to develop; a firm with a value of γ_i above .493 would not develop. From equation (15) and the data in Figure 4-3. we find:

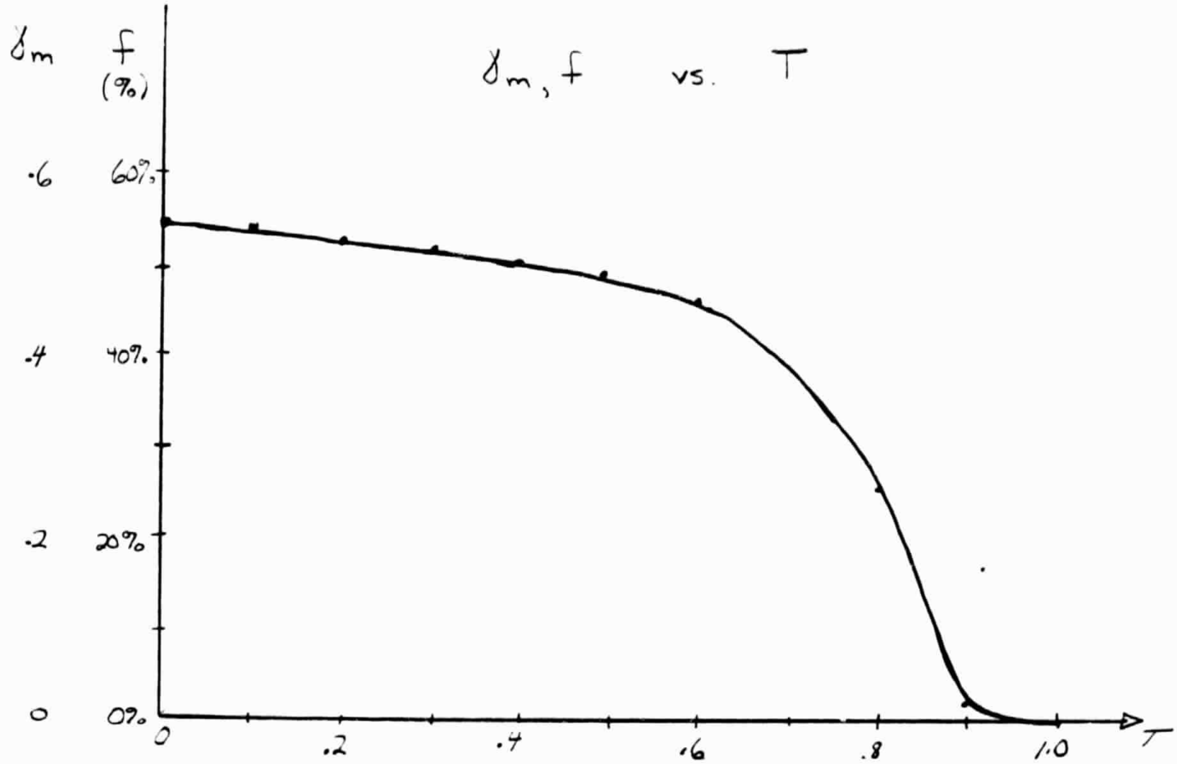
$$f = .493$$

That is, given the probability distribution on the cost parameter a_i specified in Figure 4-3, 49% of the firms in the industry can be expected to undertake development.

b) Taxation

The first policy option is to provide tax provisions for firms undertaking development. The most common form of this is through investment tax credits. Another alternative, which is considered here, is simply to adjust the corporate tax rate for these firms.

Figure 4-4 shows the effect on γ_m and f as T is shifted from its base value of 48%. As expected, γ_m increases monotonically as T declines. The effect of reducing the tax rate below 48% appears to be very limited however.



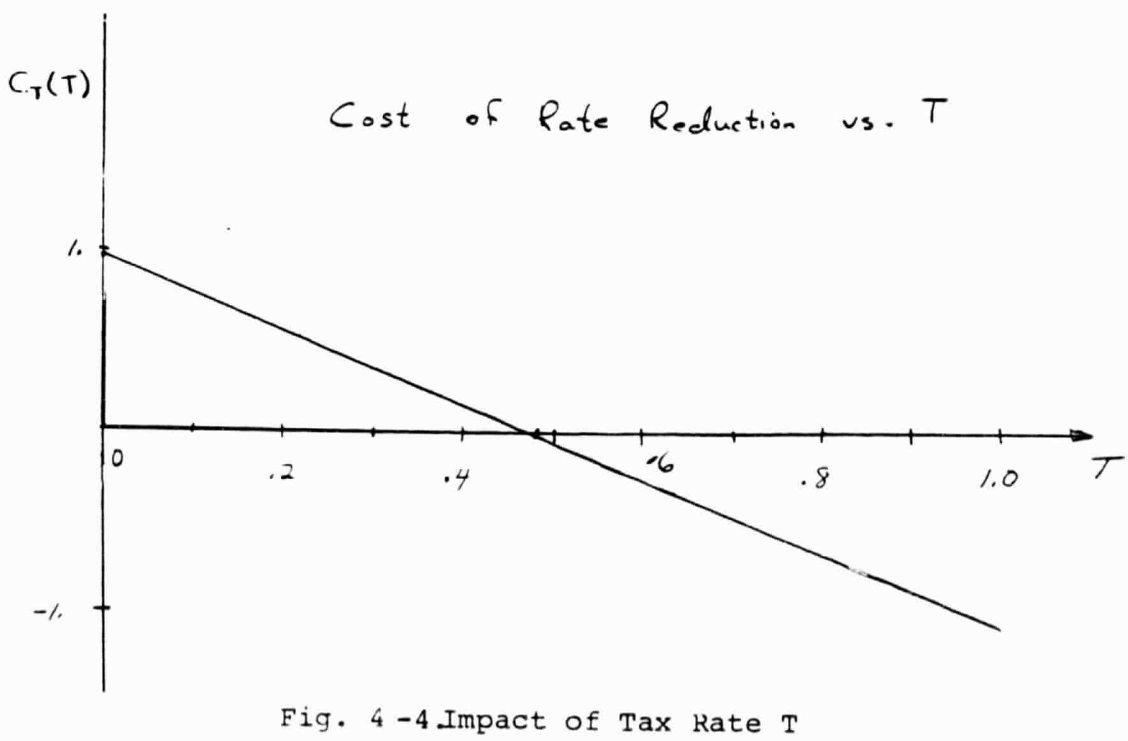


Fig. 4 -4 Impact of Tax Rate T

The cost to the government of a tax rate reduction can be calculated directly. The expected cost per firm over the period T_1 to T_2 will be

$$C_T(T) = p_3(.48-T)(1-k_3)F_2 \qquad 0 \leq T \leq 1$$

with a negative cost corresponding to increased revenues. The result is plotted as a function of T in Figure 4-4.

c) Subsidies

The variable S represents a government subsidy to firms that accrue negative profits as a result of development. Tax write-offs and loss carry-forwards can be considered to be examples of such subsidies. In the model, we simply assume that the government absorbs a fraction S of the firm's loss, if one occurs.

Figure 4-5 shows the effect on γ_m and f as S is shifted from its base setting of .50. We see γ_n increase monotonically as S increases. As S approaches 1.0, the impact is, as expected, very large. At that point the government is absorbing all of the risk of development, so there is a great incentive to develop. In the example, 100% of the firms will develop if S is equal to or greater than .7. Because this is a sample data, it is difficult to draw conclusions about the relative effect of subsidies and taxation policies. This would, however, be an interesting area for further study.

Again, it is straightforward to calculate the cost to the government of the program. The expected cost per firm undertaking development would be :

$$C_s(S) = \bar{p}_1(1-k_1)SF_1$$

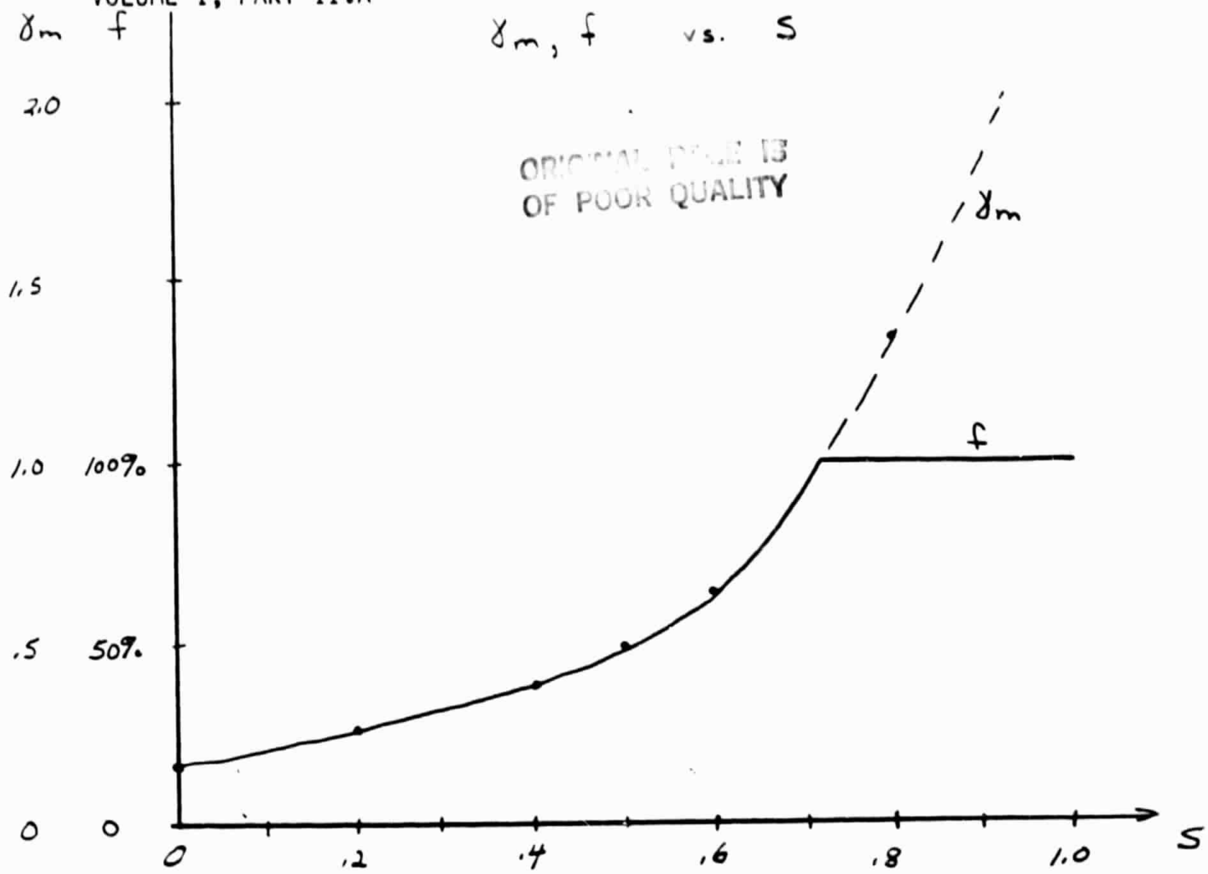
A plot of $C_s(S)$ versus S appears in Figure 4-5.

d) Direct Funding of Development

Another government option is to fund, fully or partially, development of research results derived from government projects. We assume here that the government funds the research by paying a direct subsidy to each firm undertaking development, independent of the firm's actual cost of development. In the model, this subsidy is represented as the quantity K, and is assumed to be paid at the end of Phase II. There are of course numerous other forms of direct funding, and ways of modeling it.

Figure 4-6 shows the behavior of γ_m and f as K is increased from its base value of zero. The direction of effect is as expected: as the subsidy increases, so do γ_m and f. In fact, there is a linear relationship between K and γ_m, which is due to the use of an exponential utility function in the model.

The cost of direct funding is simply K per firm undertaking development.



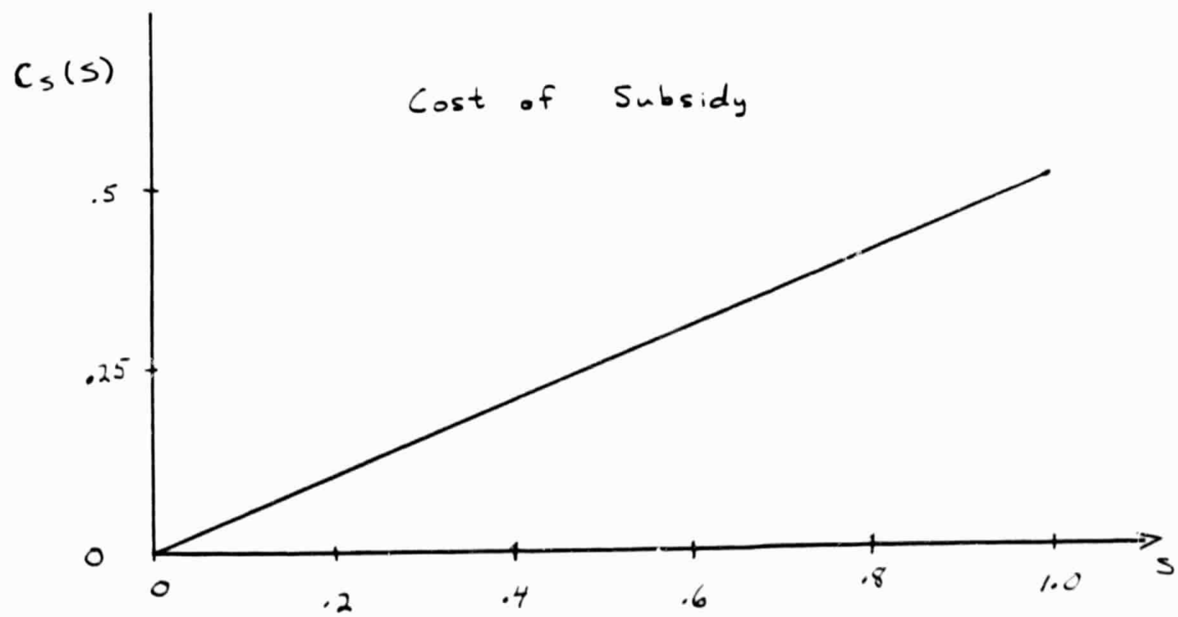


Fig. 4-5 Impact of Subsidy S

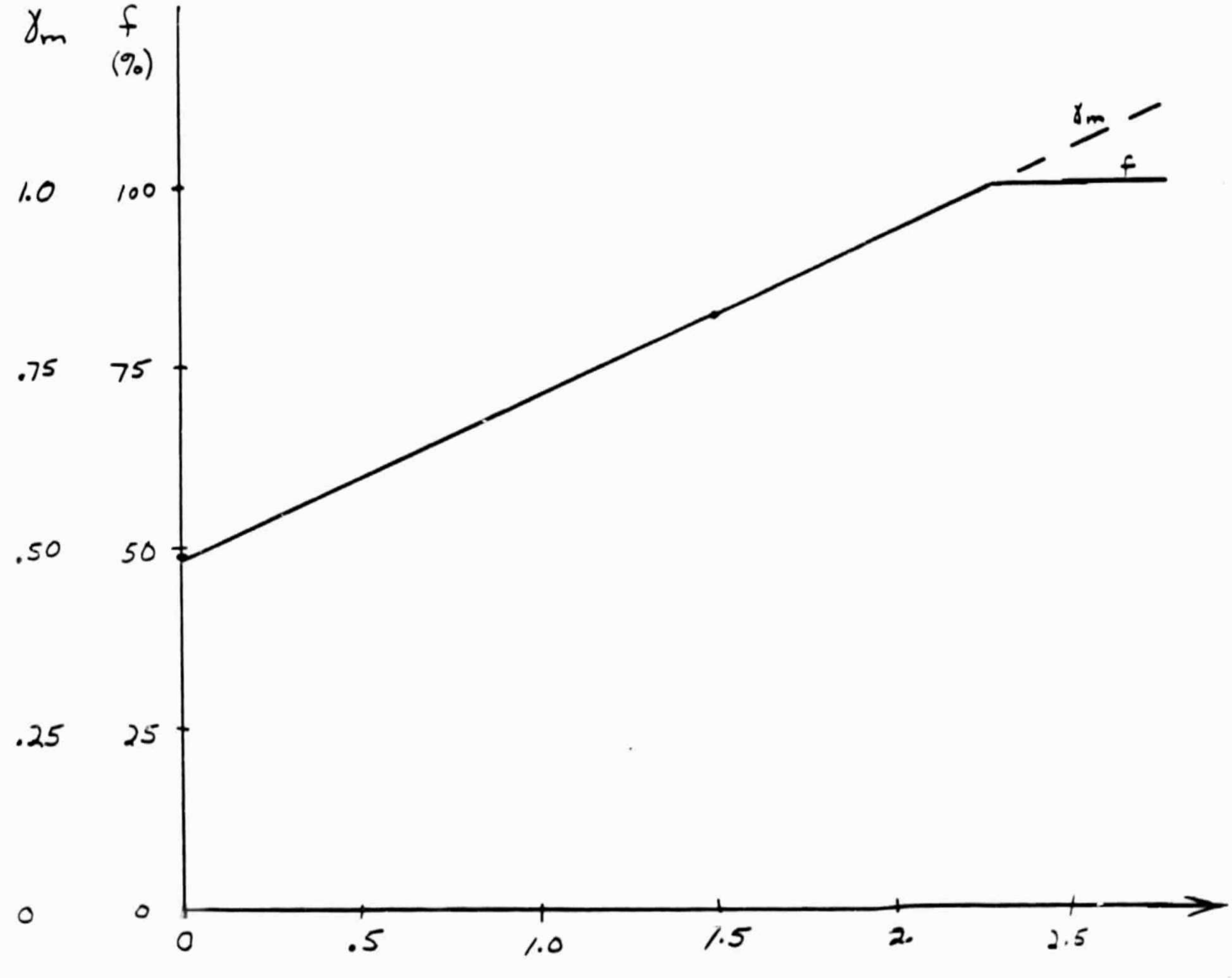


Fig. 4-6 Impact of Direct Funding of Development

e) Capital Rate Regulation

The financing of investment is not treated in detail in the model. However, a simple analysis of the effect of changes in capital rates can be performed. The model assumes that firms making positive profits have internal reinvestment opportunities, with a rate of return r_2. Firms accruing negative profits are assumed to be completely debt financed, with a borrowing rate r_1. Since there is government involvement in capital rate regulation, it is interesting to explore the effect of varying r_1. Figure 4-7. shows the effect of varying r_1 from .1 to .3. As r_1 increases γ_m and f decline, but the effect is not particularly great.

Government regulation of rates of return in regulated industries is a policy area that could be examined with an expanded version of the model.

f) Patent Length

The model assumes that a firm achieving a successful development result can maintain exclusive rights to the result throughout Phase II. This protection need not take the form of a patent· for example, long lead times required for duplication by the competition may be just as effective (see Dunn, 1979). However, we can think of this protection being afforded by a patent. By varying T_3, we can examine the impact of increasing or decreasing patent life. The result is shown in Figure 4-8. As would expected, as the patent life increases, the incentive to innovate increases. The marginal impact of increasing patent life seems to decline rapidly after a

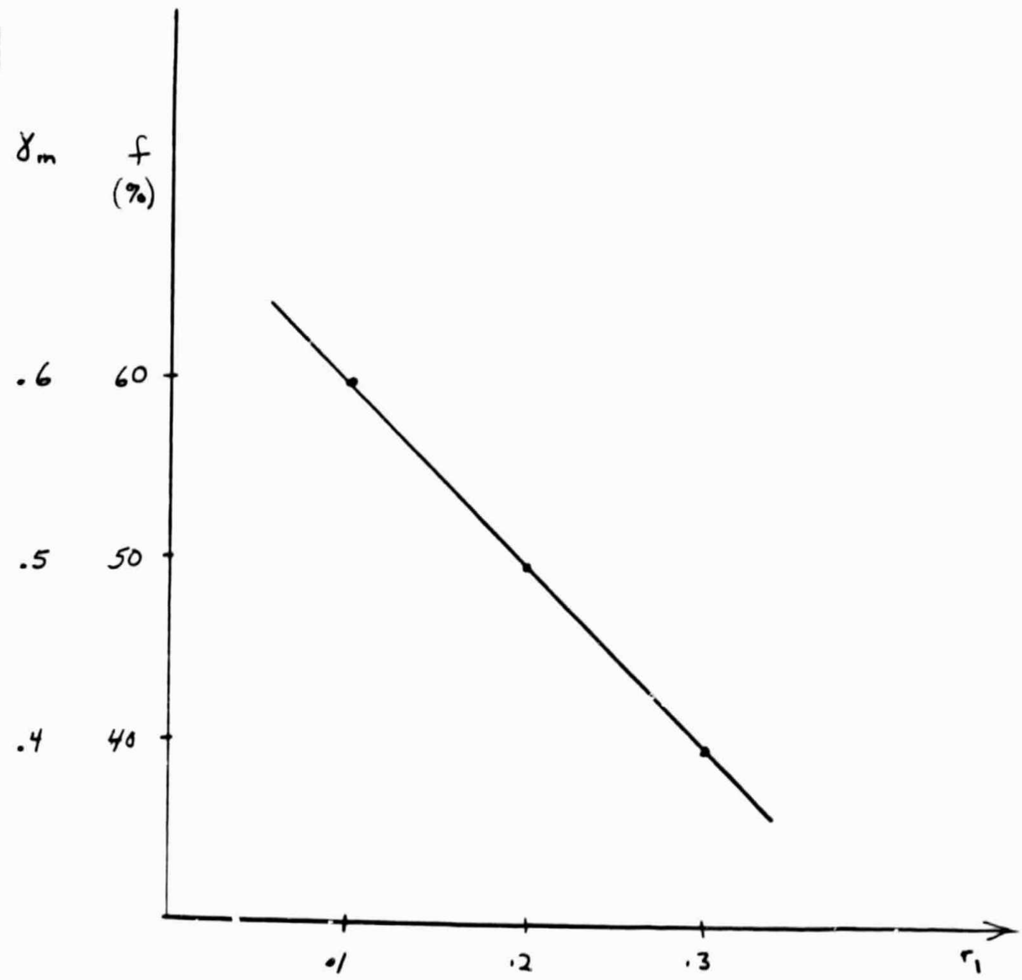


Fig. 4-7. Impact of Borrowing Rate r_1

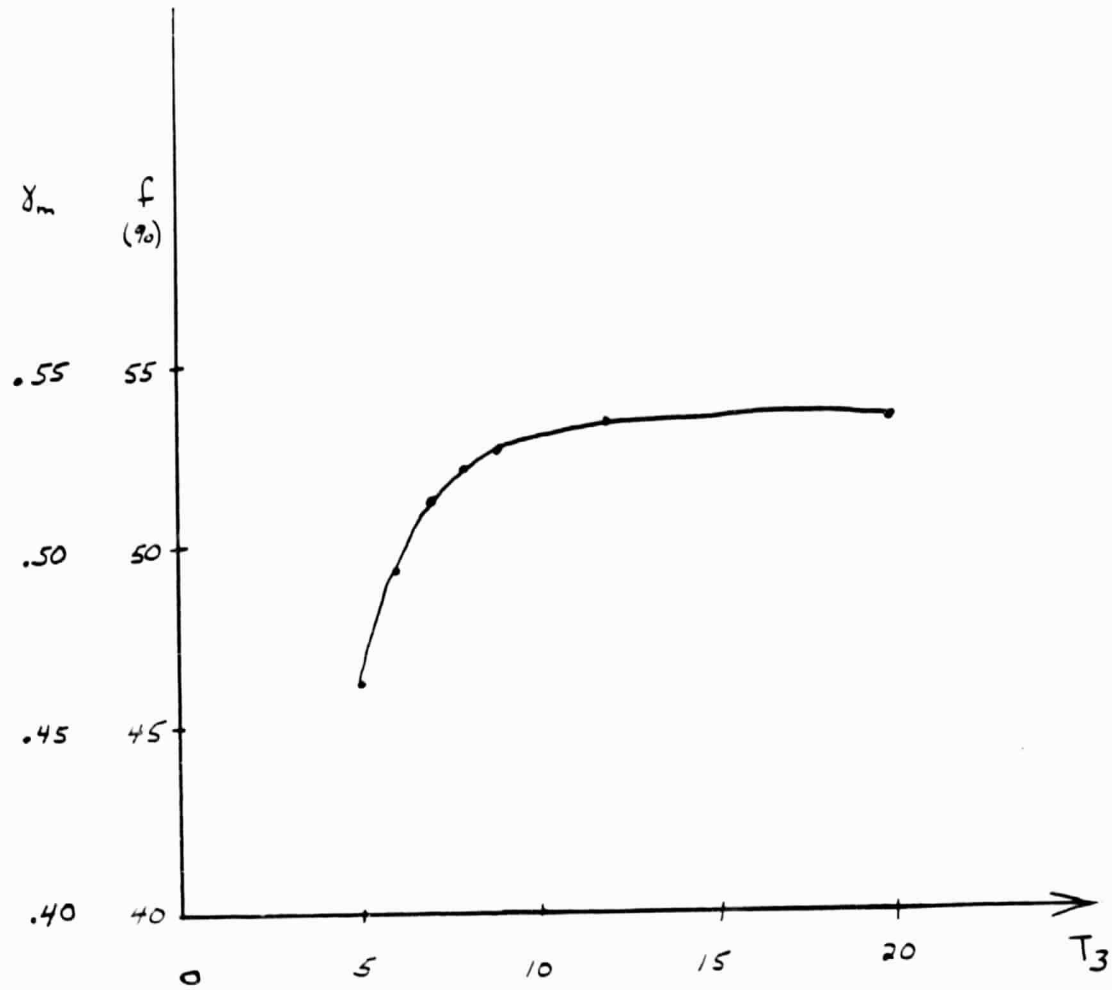


Fig. 4-8. Impact of Patent Life T_3

certain point. In general, the results seem to be surprisingly insensitive to changes in patent life.

Although increasing patent life would increase innovation, there are offsetting welfare costs. More complete analysis of the welfare effects of patents is needed before conclusions about optimal patent life can be drawn (see Nordhaus, 1967).

g) Development Assistance

The term development assistance is admittedly vague: it includes government programs such as demonstration projects, technical information services, market information services, etc.

There are several ways the effects of such programs could be represented in the model. Three of those are changing the probabilities of the various outcomes (p_1, p_2, p_3), changing the level of technical achievement (k_1, k_3), and changing T_2, the development time before an unsuccessful effort can be detected and discarded. For the sake of illustration, we will analyze the first and the third form.

Figure 4-9 shows the effect as p_3, the probability of a successful development effort, increases, while p_1 and p_2 decline proportionally. This is just one possible sensitivity run on the probabilities. It represents increased confidence in the success of the development effort. We note that when p_3 reaches the level .8, all of the firms undertake development.

Increasing T_2, the development time, could be accomplished in several ways. Government demonstration projects are one

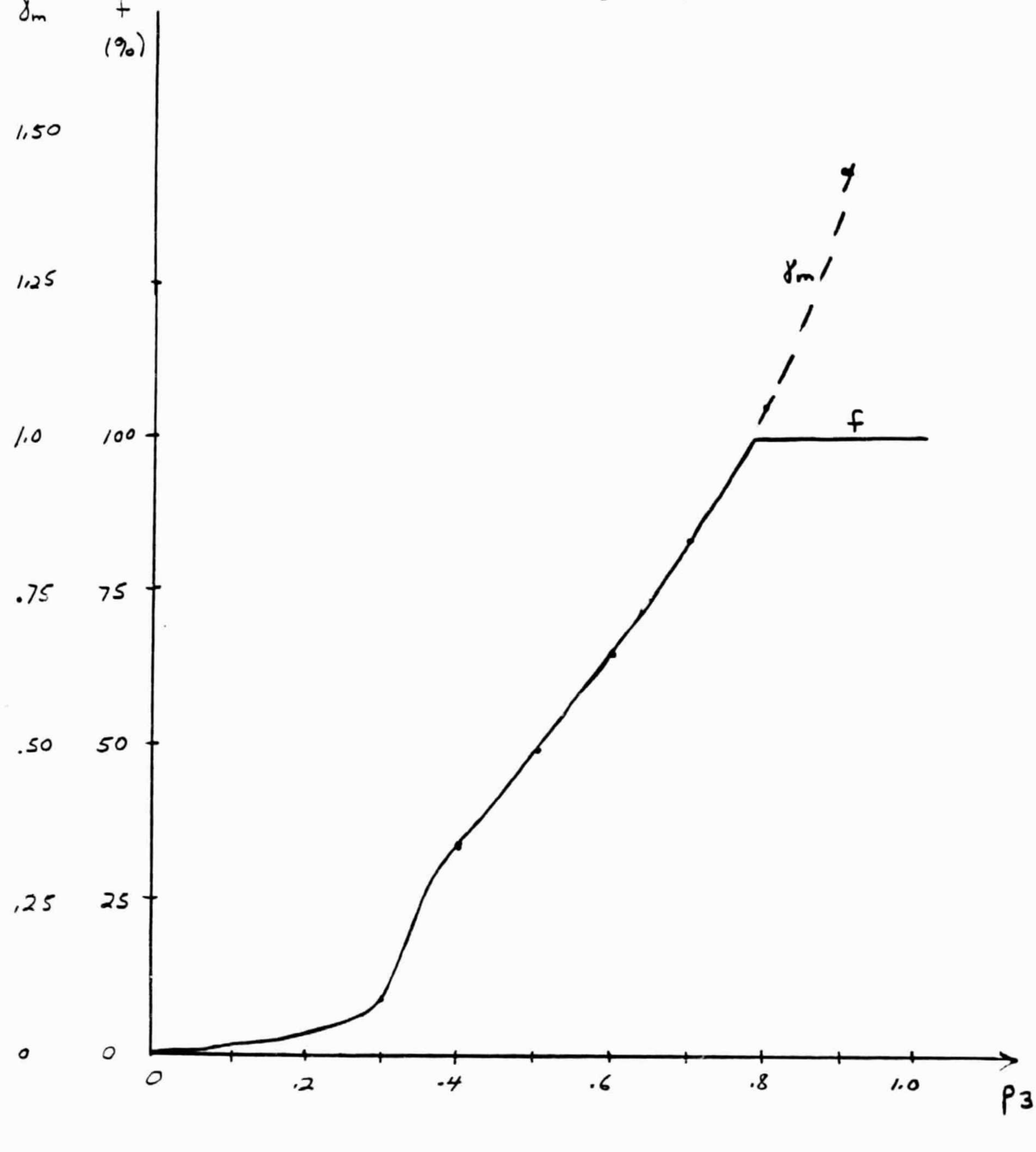


Fig. 4-9. Impact of Changing the Probability of Successful Development, P_3

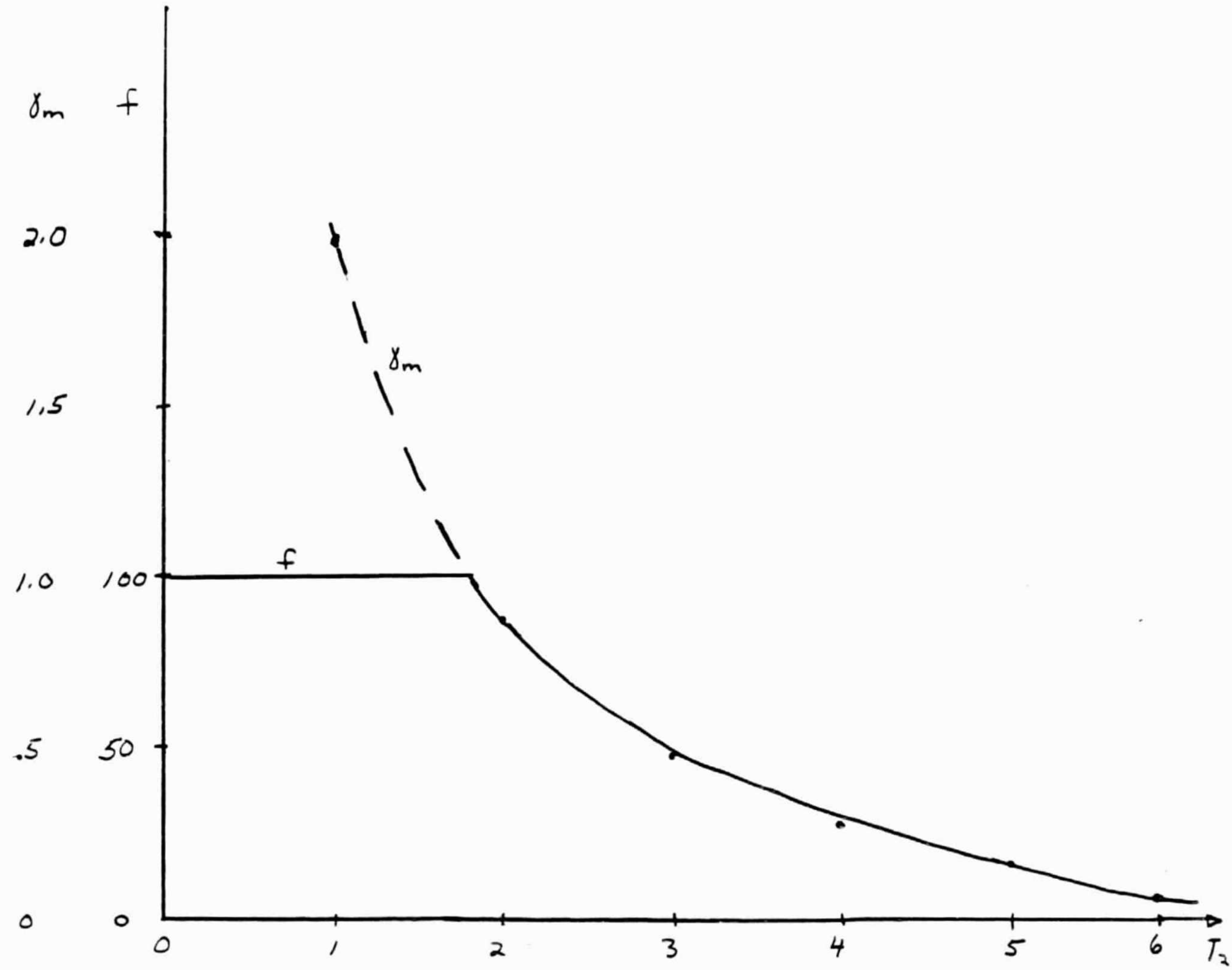


Fig. 4-10. Impact of Development Time T_2

example. Figure 4-10 shows the impact on γ_m and f as T_2 is varied around its base value of 3.

h) Encouragement of Cross Licensing

Cross licensing is a modification to standard patent and licensing procedures. Cross licensing is an agreement among a group of firms to share the rights to future inventions by any member of the group. Although there is some question as to the effect of cross licensing on free competition (and especially on new firms attempting to enter a market), it is widely used in some industries at this time (see Dunn, 1979).

The model can be modified to consider the effects of cross licensing. It is assumed that a firm has exclusive rights to its invention during the first part of Phase II, while development is taking place (from T_1 to T_2). Between time T_2 and T_3 in Phase II, the invention is shared with the parties to the cross licensing agreement.

Below, we modify the model to consider a form of cross licensing between n firms in the industry, and measure the effect on innovation as n changes. It must be pointed out, however, that the modified model does not explicitly consider the individual firm's decision to enter into a cross licensing agreement. There is a large cost to such an agreement: a major innovation that would allow the firm to substantially increase its market share and profit in absence of an agreement, must, under the agreement, be shared with a number of other firms.

Given a particular firm (which we will label Firm 1) has entered into a cross licensing agreement with n other firms, we can examine its decision to undertake development of a research result. We assume all (n + 1) firms in the agreement have the same risk aversion coefficient, so each will make the same development decision (this assumption is not essential).

Figure 4-11 outlines the elements of the development decision. During the first part of Phase II, each firm independently develops the research result, as in the original model. Again we assume one of three outcomes for the cost function parameter a_i is achieved: $k_1 a_o$, a_o, or $k_3 a_o$. Thus the probabilities and profit rates in the first part of the phase are the same as in the original model. Under cross-licensing, in the second part of Phase II, each firm either stays with its production process if it is the best developed, or moves to a process developed by one of the other n firms. The probability distribution on the best collective result of the other n firms will depend on n, as follows:

$$P(k_1 a_o | n) = p_1^{\,n}$$

$$P(a_o | n) = (1-p_3)^n - p_1^{\,n}$$

$$P(k_3 a_o | n) = 1 - (1-p_3)^n$$

The resulting profit lotteries are shown on Figure 11. For simplicity is has been assumed that K_1 is zero and r_1 equals r_2.

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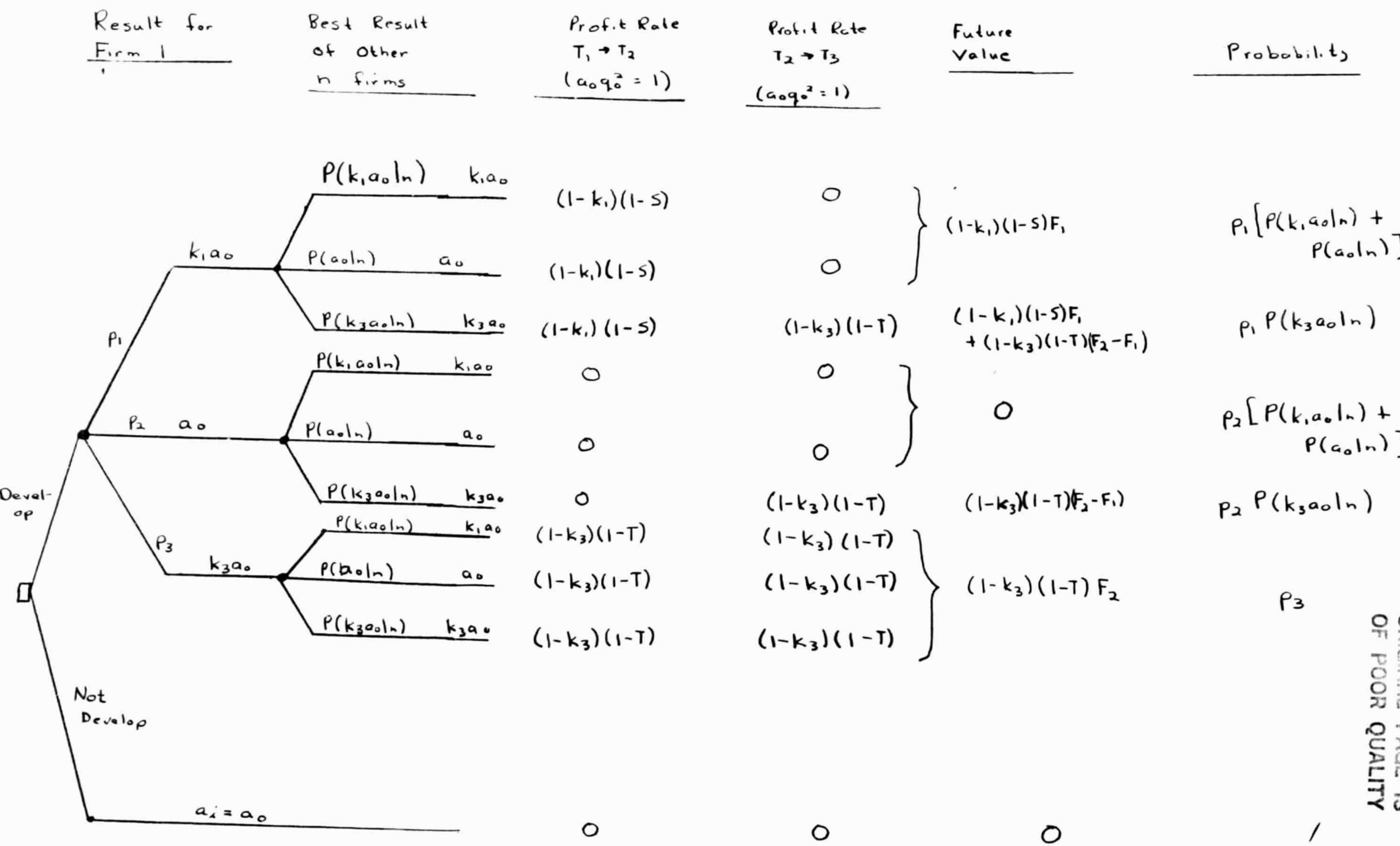

Fig. 4-11. The Firm's Development Decision with Cross Licensing

where: $F_1 = \int_{T_1}^{T_2} e^{rt} \, dt$

$F_2 = \int_{T_1}^{T_3} e^{rt} \, dt$

and $r - r = r_1$

The certain equivalent for development is:

$$
\begin{aligned}
CE_D = {} & p_1 \left[P(k_1 a_0 | n) + P(a_0 | n)\right] e^{-\gamma_i (1-k_1)(1-S)F_1} \\
& + p_1 P(k_3 a_0 | n) e^{-\gamma_i [(1-k)(1-S)F_1 + (1-k_3)(1-T)(F_2 - F_1)]} \\
& + p_2 \left[P(k_1 a_0 | n) + P(a_0 | n)\right] e^{0} \\
& + p_2 P(k_3 a_0 | n) e^{-\gamma_i (1-k_3)(1-T)(F_2 - F_1)} \\
& + p_3 e^{-\gamma_i (1-k_3)(1-T) F_2}
\end{aligned}
\qquad (16)
$$

The firm will undertake development if:

$$CE_D > CE_{ND} = -1$$

Equation (16) can be solved numerically to yield γ_m, the maximum risk aversion coefficient for development, for any value of n. From γ_m we can also calculate f, the fraction of firms implementing, in the normal way.

The results for γ_m and f for values of n between 0 and 4 are shown in Figure 4-12. The value of γ_m and f grows as n is increased. The effect is simply one of risk-sharing; the potential payoff has been increased. As stated above, there was an attending cost incurred by the firm when it entered the agreement. However given the firms are willing to enter the agreement, it is apparent a cross licensing arrangement will increase the overall level of innovative activity.

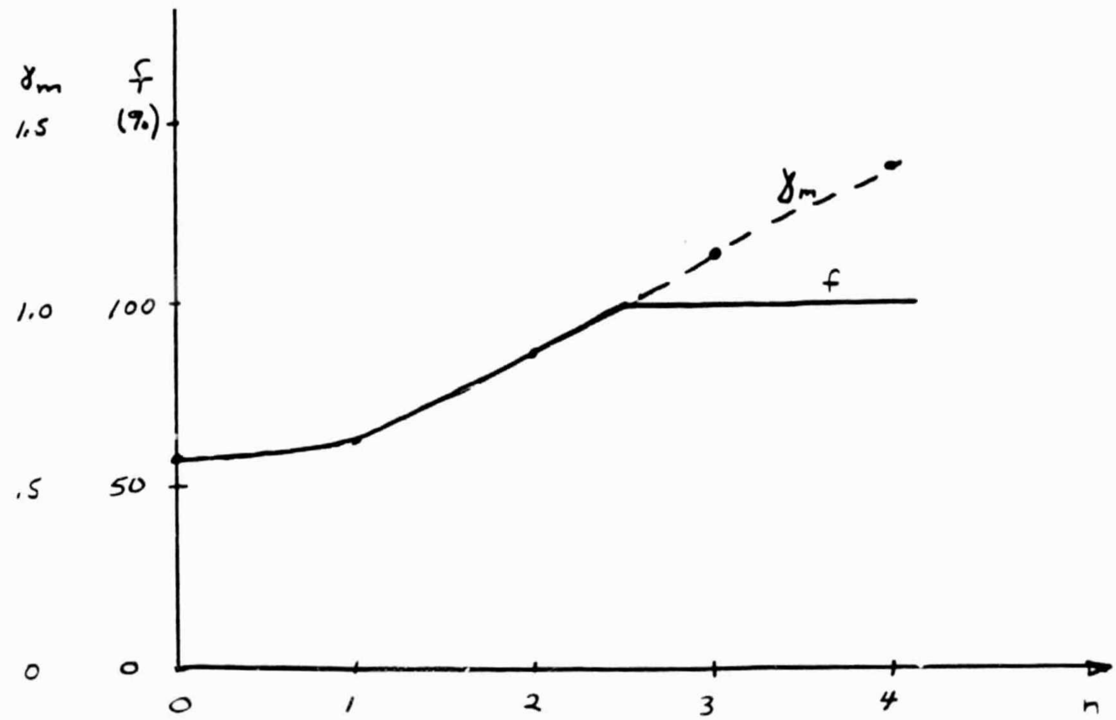

Fig. 4-12. Impact of n, the Number of Firms in the Cross Licensing Agreement

5. Conclusions

Moving from a general framework for the analysis of the technology transfer process, we have developed a preliminary economic model of the process. The reactions of the firms to commercialization opportunities, and the resulting effects in terms of social surplus, have been examined. The model has also allowed us to analyze a series of policy options relating to technology transfer.

The model could be improved in several ways. Further analytic developments, particularly in "Phase III" of the model, would be desirable, as would the elimination of several restrictive assumptions. A dynamic version of the model would bring it much closer to being a sound analytic tool, suitable for application to an actual technology transfer environment. Also, financial criteria besides profit that play a major role in the firm's development decision could be introduced, and a more thorough representation of the effects of capital availability could be included.

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GOVERNMENT PATENT POLICY

Mark Matousek
October 1979

Abstract

This paper addresses the effects of present and proposed federal patent policies on the process of technology transfer and the commercialization of inventions resulting from federally sponsored research.

The function of the patent system in government research and the value of patents resulting from government sponsored research are examined.

Three alternative patent policies--title in the contractor, title in the government, and the waiver policy--are analyzed in terms of their effects on the commercialization of inventions, industrial competition, disclosure of inventions, participation of research contractors and administrative costs.

Efforts to reform the present government patent policy are also described.

GOVERNMENT PATENT POLICY

An Analysis of the Effects of Three Alternative Patent Policies on Technology Transfer and the Commercialization of Government Inventions

Mark Matousek

Report No. 27
October 1979

National Aeronautics and Space Administration

Contract NASW 3204

PROGRAM IN INFORMATION POLICY

Engineering-Economic Systems Department
Stanford University Stanford, California 94305

ABSTRACT

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Introduction

The problems with the present patent policy for federally funded R&D--(1) lack of uniformity in individual agency policies, and (2) a very low rate of commercialization--are fairly well agreed upon, but which approach offers the best solution is still being debated with the same arguments as in 1949. But the following factors point to an increasing momentum towards some means of resolution:

--the growing concern and the resulting administrative domestic policy review over the declining rate of U.S. technological innovation;

--the recent presidential proposal for a uniform Government patent policy allowing contractors to retain exclusive licenses to resulting inventions; and

--the introduction of four bills during the 96th Congress dealing exclusively with the Government's patent policy.

The present movement in Congress to reform the Government's Patent Policy has been a long and slow moving process. Present efforts to establish a uniform policy date back to the rapid build up of government sponsored research during the second world war. Congressional patent policy guidance since that time has oscillated between a policy where the Government obtains title to all inventions arising from Government research contracts (the "title policy") and a policy where the contractor retains the title to such inventions while the Government obtains a paid-up, irrevocable license to use the invention (the "license policy").

The Carter administration recently announced its proposed Government patent policy which would allow small businesses and non-profit corporations to retain title to resulting inventions while allowing large corporations the right to obtain only an exclusive license to resulting inventions and only within a designated "field of use." This proposal is currently only a recommendation and has not been issued as a binding executive order.

There are two distinct views of the function of the patent system--as a reward for an inventor's creativity or as an incentive for the creation, development and commercialization of inventions. This paper addresses only the latter since it is this function that is important in the process of technology utilization.

The patent system was adopted in the United States to "promote the progress of science and the useful arts."[1] It accomplishes this function by providing the inventor with an exclusive right (in essence a property right) to the use of his invention. The patent system attempts to thereby encourage inventiveness, development and commercialization of inventions and the reporting of new inventions and hence the widespread public availability of new technological ideas.

There are two interpretations of the incentive function of the patent system; first, that the patent increases the incentives for people to invent socially useful (i.e., profitable) patentable technologies and that it also increases the incentives to develop, test and market (i.e., commercialize) these inventions.

Outside of Government sponsored research, the patent system's influence on calculated profit may direct the inventor's activity into channels of general usefulness. [2] But under Government research contracts, where the area and amount of research are fairly well-defined prior to the research, the major determinant of the number of useful inventions is the quality of the researchers sponsored and the level of Government funding. The ability of a contractor or specific inventor to obtain the patent rights to the resulting inventions is unlikely to greatly alter the type or quality of the research.

The more important incentive provided by patents in Government sponsored research is the incentive for the patent recipient to promote or perform the invention's commercialization and thus reap the benefits offered by the patent rights. This function has also been called the prospect function [3], since it is closely analogous to the American mineral claim system or homesteading system on public lands. The function of each is to promote the utilization of an otherwise public resource at an efficient rate which maximizes the amount of the social benefits produced.

This argument rests upon the assumptions that the $30 billion of Government sponsored research produces patentable inventions that have social value and that the ability of an inventor to capture a larger share of the invention's social benefits as profits increases the probability of the invention's

commercialization. Since social benefits are the sum of producer and consumer surplus, the profits made by the inventor still are a benefit to society. Viewed in this way, if a license policy increases the probability that a socially useful invention will be made commercially available as compared to a title policy, then it results in greater social benefits and should therefore be preferred. Therefore, the claim that a license policy is a "giveaway" of public property seems unreasonable although part of the social benefits will temporarily be in the form of private profits.

The two primary arguments against the incentive function are that patents are only a minor inducement to private firms to develop and commercialize inventions in comparison to factors such as the expected commercial value of the invention, and the cost of developing the invention; and secondly that any social benefits resulting from the patent system are outweighed by the costs resulting from the dislocation of resources caused by the patent system.

The dislocation costs refer to the outputs lost when resources are diverted to the inventing of patentable ideas from their previous use.

> "insofar as inducement (to inventive activity) is furnished only by the expectation of a patent monopoly, a diversion of resources takes place and other production is foregone. What grounds are there for concluding that the output induced by this type of monopoly has any greater claim to be regarded as 'generally useful' than that which would have been induced in its absence by the open market?" [4]

<u>The Value of Patents Resulting from Government Sponsored Research</u>

There are a number of misconceptions regarding the number and value of the patents resulting from Government funded research which have traditionally overestimated both the number and the value of these patents. As an example, there were .41 inventions per million dollars of NASA research, funded in 1978 (NASA R&D expenditures in 1978 = $3.011 billion, 1978 invention disclosures = 1239). There were .074 inventions on which patent applications were filed per million dollars of research and .044 inventions on which patents were granted (assuming the Patent Office's historical .6 ratio of patents granted to applications filed) per million dollars of research.

From this small number of patented inventions different studies have shown that from 1-20% of these will be commercially used and even a smaller number will yield any income.

The incomes yielded from those commercialized have usually been quite moderate. Therefore the expected value of the patentable inventions resulting from NASA sponsored research has been quite low. Similar results can also be found in private firms, Research Corporation, and others although the rates of both disclosure per dollar of research and commercialization of inventions disclosed have been somewhat higher.

Therefore, the claims that Government contractors that obtain patent rights may make millions of dollars is not supported in fact. Nor is the claim that the Government ownership of rights to inventions results in multimillion

dollar losses. But this is not to say that patent rights do not provide a relatively important incentive to private firms to commercialize these inventions. This relatively high perceived value of this incentive can be seen in the very active support many private firms have given to policies which allow the contractor to obtain exclusive rights to the invention.

Analysis of Alternative Patent Policies

This section of the paper examines the policies--the title policy, the license policy, and NASA's present waiver policy--upon the basis of the costs and benefits resulting from each policy. The costs and benefits are broken down into the policies' effects in five sectors:

- o commercialization or utilization of inventions,
- o competition,
- o participation of contractors in Government research,
- o disclosure of inventions, and
- o administrative costs of the program.

This report does not place quantitative values on these costs and benefits because of the unavailability of sufficient data to give reliability to such results.

Commercialization of Inventions

The effect of Government patent policy on the rate of utilization of Government sponsored inventions has traditionally been the most important issue in the debate between advocates of the title and license policies. Commercialization is

important because it is the major means by which an invention reaches the public and its advantages (cost reduction, increased product quality, ...) are transformed into social benefits. Most supporters of the license policy have claimed that the increased likelihood of commercialization of inventions is the greatest advantage in allowing contractors to retain exclusive rights to their inventions. This argument is based on the assumptions that most high technology companies are more capable of promoting the dissemination and use of inventions than the Government and that exclusive rights provide a necessary incentive to bring forth the risk capital necessary for the development, marketing, and commercialization of new inventions. Title policy proponents have responded that not only are patents a minor determinant in corporate decisions to commercialize inventions, but the potential inability of interested future developers to gain access to the technology results in an actual decrease in the likelihood of commercialization.

License Policy Arguments:

There are two major arguments behind the position that the ability of contractors to retain title to inventions will increase the rate of commercialization of Government sponsored inventions;

- o a patent provides a contractor with the exclusive right to license or use an invention, resulting in a reduction of the risks accompanying its development and commercialization and thereby increasing

the incentives for the investment of the necessary risk capital,

- o contractors who have retained title to inventions have been more successful at commercializing those inventions than the sponsoring agency, in part because of their closer tie to the marketplace and prospective developers (oftentimes the contractors themselves) and the possession of a product "champion" (the inventor himself).

The first of these two arguments is based upon the "prospect" theory of a patent (discussed in the previous section). This view of the patent system envisions the patent, not as a reward for past inventiveness, but as a necessary incentive to develop, test, and use or market an invention. Traditionally, the cost required for development and commercialization of an invention have been an order of magnitude (or more) larger than the basic research costs. For NASA inventions, the private or public utilization of space technology usually requires large costs in adaptive engineering, development and marketing. By reducing the risk of other companies appropriating the results of this process of commercialization, patents provide a greater incentive for contractors to invest capital and, the Harbridge House Study on Government Patent Policy pointed out, it is the lack of full technical development of Government inventions that has been the most frequent and important barrier to industrial use [5]. A patent does not disallow others from

using a patented technology, it only demands that they negotiate a reasonable payment for its use with the patent owner.

One result of this incentive is an increase in the amount of private resources being expended on technological innovation, an increase which most economists have regarded as being important both in reversing the declining levels of U.S. productivity and in modernizing technological industries that have fallen behind foreign competitors.

In support of the second argument, there is statistical evidence that contractors actually have been substantially more successful than the Government in promoting the commercialization of Government sponsored inventions, either through inter-corporate licensing or in-house development. Of the over 1200 NASA inventions to which contractors have obtained title since 1959, approximately 16% have been commercialized (Appendices B and C). In comparison, of the over 3500 inventions to which the Government has acquired patents since 1959, only 1% have been commercialized (Appendices D and E).

These figures are subject to question because of the difficulty in obtaining data many years after initial invention, the variation in definitions of "commercialization" and the statistical bias caused by contractors requesting the most commercially attractive inventions under a waiver policy. This variation is indicated in Appendix F showing the results of five different studies of the commercialization of NASA inventions. The most reliable data is probably that

compiled by NASA's patent and licensing office, since their data gathering techniques are the most extensive and their definitions have been subject to only minor variations over time (Appendices B, C, D, and E).

These higher rates of commercialization by contractors are caused in part by contractors requesting waivers on the commercially valuable inventions, but there are a number of other factors also involved. Contractors are usually chosen because of their being the most qualified in a certain field of research and, therefore, they are often in the best position to promote the commercialization of inventions in that field. These companies or universities as a result usually have much closer ties to the marketplace than do the sponsoring agencies. These contractors are also guided by the profits that inventions can offer to channel their investments into areas of public usefulness. They also have greater freedom in the types of license agreements that they can subsequently negotiate with other users of the invention.

Contractors also already have a "product champion" since it is usually the inventor that has the greatest interest in seeing an invention actually developed and utilized. It is widely believed that the transfer of a technology from one organization to another requires the transfer of people familiar with the technology. One obvious solution is to provide inventions to the organization possessing the technology to develop it themselves. Patent rights provide this type of incentive.

It is interesting to note that the patent attorneys at several agencies, including agencies which now pursue a waiver policy, have informally supported the use of a license policy in almost all Government research contracts (Appendix G).

Title Policy Arguments:

There are three major arguments against contractors being allowed to retain title to inventions in order to encourage commercialization:

- o patents play a minor role in determining corporate decisions to commercialize inventions in comparison to factors such as favorable price conditions, the state of business confidence and costs of capital;
- o contractors retaining title to Government sponsored inventions are oftentimes interested in only making sure that their competitors don't use the inventions, thereby decreasing the likelihood of commercialization;
- o it is impossible to show that the gains from the movement of people and funds to the development of patentable inventions are not offset by losses in other areas of output--specifically the development of non-patentable inventions.

Waiver Policy Arguments:

The waiver policies adoped by NASA, DOE, NSF, and HEW have offered several advantages. They are flexible and therefore allow contractors interested in commercializing an invention a chance (a 76% chance at NASA) to obtain exclusive rights to

an identified invention. In those cases where the contractor has not expressed an interest in the invention, or the waiver has been denied, the Government then has the opportunity to seek out other possible users on an exclusive or non-exclusive basis. Such a flexible system initially appears to offer the advantages of both the license and title policies, but there are a number of disadvantages as well.

It is obviously impossible for NASA's Invention or Contribution Board or DOE's patent office or any other Government entity responsible for waiver decisions to be able to know what the necessary factors are in an invention's commercialization.

Commercialization is dependent upon a number of complex unknowns such as future market demand, the quality of the invention, and the companies interest in the invention. Also present waiver guidelines support Government retention of title in cases where the "principal purpose of the contract is to create, develop or improve products, processes or methods which are intended for commercial use" or "which directly concern public health, public safety or public welfare," areas where it seems incentives to commercialize the inventions are the most important (see Appendix A).

Past records also show that many contractors perceive the waiver process as cumbersome and resulting in a waste of both time and money. Processing time for a waiver by NASA can vary from several weeks to a year depending upon the perceived urgency of the request. A waiver must also be

accompanied by a general outline of the contractor's proposed plan for the invention's commercialization. For large companies familiar with NASA's waiver process, the waiver requests do not pose a high cost. But for small companies or those unfamiliar with the waiver process, the costs of a waiver request may appear to be very substantial. Some NASA contractors have reported that they were unaware that waivers were even granted.

Another problem with the waiver system is that it introduces a factor of uncertainty in the commercialization process. An example of this uncertainty is provided by the changes that took place in HEW in 1978. Up until that time, HEW had followed a policy of granting most waiver requests to universities and small businesses (under Institutional Patent Agreements). Many contractors had participated in HEW contracts with this expectation, but in 1978 Secretary Califano called for a review of all future waivers and essentially froze all future waivers.

Effects on Industrial Competition

Opponents of a license policy have argued that the ability of contractors to retain patent rights has resulted in the formation of product monopolies, the increase of product costs to the consumer, and the lessening of market competition. Although patent rights do permit the private capture of returns created by the use of a patented invention, they by no means assure it. In fact, past studies have shown no significant examples of monopolization resulting from patents obtained on

Government sponsored inventions with the most extensive patent policy study concluding "that undue concentration would result from the license policy is a possibility so negligible that it may be disregarded" [6].

The main reason that contractor retained patents have not resulted in monopolization is, as previously mentioned, that there are few patented inventions of sufficient quality to allow the capture of a market. It is interesting to note that in thirty-four antitrust cases studied by the Harbridge House, where forced licensing of the defendent's patent portfolio had been one of the economic remedies for restraint of trade, only two companies in the survey have ever received applications for licenses although the patent portfolios were in some cases as large as 300 patents [7] .

Monopolization has also not occurred because contractors have in general been very willing to license the use of their inventions to other users. In fact licensing has oftentimes provided the contractor with the most valuable means of optimizing the value of the patent, either in addition to or in place of in-house development.

A more reasonable concern than monopolization is that a few valuable inventions will be neither utilized nor promoted by the contractor. Since NASA currently publishes Tech Briefs and Technical Support Packages on contractor-owned patents arising from NASA sponsored research, this lack of use is presently minimized.

C-2

It should also be noted that the Government presently has a means of protecting against monopolization, "excessive profits" or non-use of an invention in the form of "march-in-rights." March-in-rights give the sponsoring agency the right either to require the contractor to license an invention to another company at a reasonable rate or to license the invention itself under certain limited conditions. Although march-in-rights have never been enforced, it seems that they could be used effectively in the few situations where they might be needed.

Of several agency patent counsels interviewed, a few stated that for march-in-rights to be effective the sponsoring agency must monitor the contractors' use of the invention through the submission of a contractor's invention utilization report. The submission of the utilization reports was said also to increase the likelihood of the contractor using the invention by encouraging a careful assessment of the invention's commercial value. Such a monitoring program could result in enforcement through the action of the contractor's competitors who could, in the case of valuable inventions, monitor their misuse and request the Government to enforce its march-in-rights.

It has also been suggested that when a contractor has not used the invention after a certain number of years that the patent rights should be transferred back to the sponsoring agency, so that it can promote the invention's utilization. However, such a proposal is plagued by the problem of defining a "reasonable

period of time" and what constitutes use of an invention.

Participation of Contractors

The willingness of a contractor to participate in Government sponsored research is highly dependent upon two factors: the contractor's perceived value of any resulting patents to which he may retain exclusive rights and the reasons a company enters into Government sponsored research.

For those companies that regard patents as an essential form of protection in developing a new product, the title policy may oftentimes deter the company from entering into a Government research contract. Past studies have shown that such companies are not in the majority and are concentrated in industries which are technologically based but innovate at a moderate rate (excluding rapidly innovative industries where trade secrets provide a more effective means of protection).

Many companies, especially large corporations, have traditionally regarded patents as being essentially defensive in nature (i.e., means of avoiding lawsuits for infringement by other companies who later patent a similar invention). For these companies, gaining exclusive rights to Government sponsored inventions has little value since the Government does not enforce infringement on the patents that it owns. The participation of those companies which see patents as having neither offensive nor defensive value are essentially unaffected by Government patent policy although several such companies have nonetheless vigorously supported a license policy.

Those companies which do value patent rights might be expected to lower their contract bids under a license policy by an amount proportional to the perceived value of the exclusive rights in any future inventions, although there has been no good evidence to substantiate such a belief. The value of potential patents rights to a contractor before performance of the contract are estimated to be worth less than one dollar ($1) for an average one million research contract [8].

Many of the opponents of the title policy have claimed that that policy's major disadvantage is not the inflated cost of contractor's research bids but the lower quality of research that the Government obtains. This lower quality is due to a number of factors including the refusal of many of the most qualified contractors to perform Government research. Surveys of companies have shown that only a few companies actually refuse to participate because of an agency's patent policies. Lack of interest in the area of research, unwillingness to transfer the necessary personnel and facilities away from commercial research and a general unwillingness to work under Government supervision have been the more common reasons for qualified contractors not participating in Government research.

One area where contractor participation has been adversely affected is in contracts which require the availability to the public of any background patents; i.e., those privately owned patents which are deemed necessary for the use of any inventions

resulting from subsequent Government contracts. Companies have also claimed that participating in Government contracts has resulted in valuable proprietary information becoming publicly available because of the Freedom of Information Act and the requirement for background patents (Appendix G).

There have also been claims that a large number of contractors segregate their industrial research teams from their Government research, resulting in a lower quality of Government research. If corporations' proprietary information has been jeopardized, such segregation seems to be a reasonable response.

NASA's ability to grant advance waivers should decrease the likelihood of losing the participation of qualified contractors. Advance waivers have been requested from NASA 906 times and granted 463 times between 1958 and 1978. Although considering how few advance waivers are requested, contractors apparently either perceive the waiver requests as time consuming and/or too expensive, or the value of obtaining patents is too low to justify such requests. Although the waiver request requires only the completion of a prepared form and the identification of the contractor's ability to commercialize or license any resulting inventions, many small companies are not aware of the process or view it as too expensive. This can be seen from the fact that the vast majority of NASA waiver requests come from large companies familiar with NASA's waiver policies.

Disclosure of Inventions

All Government research contracts require that contractors report any resulting inventions to the sponsoring agency. Disclosure is considered so important by some that a draft bill proposed by the Departments of Commerce and Justice in 1979 recommended criminal sanctions against any contractor not reporting new inventions. Aside from the complete infeasibility of such a proposal,* it indicates the fear by some Government officials that there are contractors who do not disclose inventions they see being commercially valuable and thus decrease the social benefits gained from the research.

A high rate of disclosure by itself is not advantageous, as can be seen from NASA's records. Some companies have traditionally reported large numbers of inventions that never proved of any commercial value, while others have only reported those inventions that they thought to be novel breakthroughs. Although the cost of screening an invention is not very high, since 1963 contractors have reported an average of nearly 1800 inventions annually, while only 5% of these have resulted in patent applications. In comparison, NASA employees have reported only an average of 335 inventions annually with 34% resulting in patent applications. It, therefore, is obvious that promoting disclosures is of and by itself of little value.

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* Due to the inability to definatively define what constitutes an invention or the inability of, for example, a scientist in one field to recognize that his minor discovery may be a breakthrough in a completely different field.

It is not obvious that any patent policy is clearly advantageous in promoting the disclosure of valuable inventions. License policy advocates have claimed that the ability to retain exclusive rights would remove the disincentives for not reporting inventions. Yet in those contracts where NASA has granted advance waivers the number of inventions disclosed per dollar of research has declined substantially, although much of this is due to the contractor's diminished need to disclose inventions that are not of a patentable or otherwise valuable nature.

As the Deputy Assistant Attorney General for Antitrust matters recently remarked--

> "We do not believe that disclosure has been a problem in private R&D contracting situations largely because of the high costs of concealment and the penalties in loss of reputation and future business caused by having concealment later discovered." [9]

Although there is little conclusive evidence to show that any one patent policy results in a more complete and effective disclosure of inventions, there is some evidence indicating that NASA's attempts to promote disclosures from contractors have resulted in an excess of disclosures of inventions that have little or no commercial value, wasting the time and money of both the contractor and the Government invention review board. This cost must, of course, be weighed against the possibility that a few valuable inventions might otherwise not be reported.

Administrative Costs

The administrative costs of each of the three Government patent policies is not very substantial and are unlikely to be a major factor in choosing between each policy. Nonetheless changes in policy could offer some cost reductions in comparison to NASA's waiver policy.

Presently the costs directly and indirectly attributable to NASA's waiver policy stem from the following activities;

1) compilation of the inventions disclosed by contractors and employees,
2) screening of the inventions by NASA and IITRI,
3) processing and filing of patent applications,
4) compilation of waiver requests,
5) compilation of licensing requests,
6) determination of waiver and license requests by the ICB,
7) review of the invention utilization reports, and
8) promotion and description of NASA inventions by the Technology Utilization office.

The license policy would decrease these administrative costs by decreasing both the number of inventions that must be screened for patent applications by the Technology Utilization office, eliminate the compilation and determination of waiver requests, decrease the number of license requests and determinations, and increase the number of invention utilization reports.

The title policy would increase the number of inventions to be screened, patented, licensed, and promoted and would eliminate the waiver compilation and determinations.

Several critics of NASA's present policy have claimed that NASA files patent applications on many more patents than are necessary. Since the Government only uses patents defensively, except when it is granting exclusive licenses, publication will give the same defense against infringement but without the cost of the patent application processing and filing fees.

Appendix A

NASA's Patent System

NASA's patent policy is based upon Section 305 of the National Aeronautics and Space Act of 1958 and the Presidential Memorandum on Government Patent Policy of 1971 (PRM). NASA's policy and procedures are detailed in NASA's revised implementing regulations (e.g., NASA Patent Waiver Regulations [10]; NASA Domestic Patent Licensing Regulations [11] ; and NASA Foreign Patent Licensing Regulations [12]).

NASA's patent policy has evolved into a waiver policy which retains for the Government a broad, irrevocable royalty-free license but allows Government contractors to request the Government to waive its rights to the title of an invention to the contractor. Invention waivers may be requested either prior to performance of a contract for all resulting inventions (advance waivers) or after identification of an individual invention under a given contract. Recommendations on all waiver requests are made by the NASA Inventions and Contributions Board (ICB) to the NASA Administrator although almost no ICB recommendations have ever been reversed by the Administrator.

Guidelines to be considered by the ICB in considering waiver requests are outlined in the Space Act, Presidential Memorandum of 1971 and the implementing regulations. The stated objectives of NASA's patent policy are:

- o serving the public interest;
- o protecting public health, safety and welfare;
- o fostering inventiveness;
- o encouraging reporting of inventions;
- o providing for the widest possible dissemination of new technology;
- o promoting the investment of risk capital in new inventions;
- o promoting industrial competition;
- o promoting early utilization of inventions; and
- o avoiding undue market concentration.

There are similar guidelines of each Federal agency but widely varying interpretations of these objectives has resulted in each Federal department or agency developing a different patent policy.

Statistically, NASA's policy has been largely one of title in the Government with contractors acquiring title to only 4% of the contractor inventions disclosed. [13] This low percentage of contractor acquired rights is due primarily to the small number of contractor requests for waivers. Between 1959 and 1979, 76% of the requests for individuals' waivers had been granted with 51% of the requests for advance waivers being granted.

From these figures it would appear that either NASA has been patenting many inventions that their inventors do not perceive as having significant commercial potential and for

which the Government's rights could probably be just as effectively protected by publishing, or the process of requesting a waiver is or at least appears to contractors to be an overly expensive or time consuming obstacle to gaining title to an invention, or both.

NASA'S PATENT POLICY

Title In The Government

1) National Aeronautics and Space Act (1958):

"any invention conceived or actually reduced to practice in the performance of any work under any contract... becomes the exclusive property of the government unless the Administrator determines that the interests of the United States will be served by waiving all or any part of the Government's rights...." (section 305)

2) Presidential Memorandum (1971):

(a) Where

(1) a principal purpose of the contract is to create, develop or improve products, processes, or methods which are intended for commercial use (or which are otherwise intended to be made available for use) by the general public at home or abroad, or which will be required for such use by governmental regulations; or

(2) a principal purpose of the contract is for exploration into fields which directly concern the public health, public safety, or public welfare; or

(3) the contract is in a field of science or technology in which there has been little significant experience outside of work funded by the Government, or where the Government has been the principal developer of the field, and the acquisition of exclusive rights at the time of contracting might confer on the contractor a preferred or dominant position; or

(4) the services of the contractor are

(i) for the operation of a Government-owned research or production facility; or

(ii) for coordinating and directing the work of others (Section 1)

Title In The Contractor

1) National Aeronautics and Space Act:

No such allowance mentioned.

2) Presidential Memorandum:

(b) In other situations, where the purpose of the contract is to build upon existing knowledge or technology, to develop information, products, processes, or methods for use by the Government, and the work called for by the contract is in a field of technology in which the contractor has acquired technical competence (demonstrated by factors such as know-how, experience, and patent position) directly related to an area in which the contractor has an established nongovernmental commercial position, the contractor shall normally acquire the principal or exclusive rights throughout the world in and to any resulting inventions.

(c) ...the agency may prescribe by regulation special situations where the public interest in the availability of the inventions would best be served by permitting the contractor to acquire at the time of contracting greater rights than a nonexclusive license. (Section 1)

3) Institutional Patent Agreements:

In accordance with the language regarding exceptional circumstances in §1-9 107-3(a) and/or the language regarding special situations in §1-9 107-3(c), agencies may enter into Institutional Patent Agreements (see §1-9 107-6(c)) with universities and nonprofit organizations having technology transfer programs meeting the criteria of §1-9 109-7(b). The agreements permit those institutions, subject to certain conditions, to retain the entire right, title, and interest in inventions made in the course of their contracts.

Waivers

1) National Aeronautics and Space Act:

(f) Under such regulations in conformity with this subsection as the Administrator shall prescribe, he may waive all or any part of the rights of the United States under this section with respect to any invention or class of inventions made or which may be made by any person or class of persons in the performance of any work required by any contract of the Administration of the Administrator determines that the interests of the United States will be served thereby. (Section 305)

2) Presidential Memorandum:

Advance Waivers;

In exceptional circumstances the contractor may acquire greater rights than a nonexclusive license at the time of contracting where the head of the department or agency certifies that such action will best serve the public interest. (Section 1(a))

...the agency may prescribe by regulation special situations where the public interest in the availability of the inventions would best be served by permitting the contractor to acquire at the time of contracting greater rights than a nonexclusive license. (Section 1(c))

Deferred Determination Waivers;

Greater rights may also be acquired by the contractor after the invention has been identified where the head of the department or agency determines that the acquisition of such greater rights is consistent with the intent of this Section 1(a) and is either a necessary incentive to call forth private risk capital and expense to bring the invention to the point of practical application or that the Government's contribution to the invention is small compared to that of the contractor. Where an identified invention made in the course of or under the contract is not a primary object of the contract, greater rights may also be acquired by the contractor under the criteria of Section 1(c). (Section 1(a))

Appendix B

NASA WAIVER STATISTICS
1959 THROUGH 1978*

Individual Waivers

1.	Number of inventions reported by NASA contractors	31,357
2.	Petitions for waiver requested	1,366
3.	Waivers granted	1,035
4.	Petitions denied	148
5.	Petitions withdrawn	139
6.	Petitions pending	44

Advance Waivers

1.	Advance waivers requested	906
2.	Advance waivers granted	463
3.	Advance waivers denied	293
4.	Requests withdrawn	111
5.	Requests pending	39
6.	Number of inventions reported under contracts having advance waivers and contractor intends to file	216

Inventions Waived

1.	Total inventions waived		1,254
	Under individual waivers	1029	
	Under advance waivers	225	
2.	Inventions for which waivers have been voided		266

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* Statement of Gerald Mossinghoff, NASA Deputy General Council, before the U.S. Senate Subcommittee on Science, Technology and Space, July 23, 1979.

Appendix C

UTILIZATION/COMMERCIALIZATION STATISTICS ON WAIVED INVENTIONS*

Number of Waived Inventions Surveyed:	121
Percent of Total (788) Active† Inventions:	15%
Total Number of Responses:	102
Percent Response:	84%

Types of Inventions Surveyed	Reports Requested	Reports Received	Percent Response
Previous Indications of Probability of Use in 1977-1978	100	83	83%
Newly Waived Inventions	13	12	92.3%
Nonresponsive to 1977 Request	8	7	87.5%

Status of Surveyed Inventions	Number of Inventions
Utilized/Commercialized (First Use-2 inventions)	7
Development Efforts Continuing	39
Licensing/Promotion Only	34
No Further Development Expected	22

Total Number of Active† Inventions (Through 1977):	788
Total Number of Inventions Voided:	258
Total Number of Inventions Utilized/ Commercialized:	193 (18.5%)

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* See Appendix B

† Waiver not voided

Appendix D

NASA LICENSING STATISTICS
U.S. PATENTS AND PATENT APPLICATIONS
December 31, 1978*

U.S. PATENTS HELD BY NASA

U.S. Patents and Patent Applications Available for Licensing	3,512
Employee Inventions	2,378
Contractor Inventions	1,134

NONEXCLUSIVE LICENSES

Licenses Granted to Date	502
Licenses Revoked or Terminated	260
Licenses in Force as of this Date	242
Inventions Covered by Licenses in Force	124

EXCLUSIVE LICENSES

Licenses Granted to Date	21
Licenses Revoked or Terminated	12
Licenses in Force as of this Date	9
Inventions Covered by Licenses in Force	9
Different Licenses	8

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* See Appendix B

Appendix E

COMMERCIAL USE OF NASA OWNED INVENTIONS LICENSED BY NASA IN THE UNITED STATES December 31, 1978*

NONEXCLUSIVE LICENSES

Nonexclusive license in force	242
Utilization reports received from licensees . . .	138
POSITIVE USE REPORTS	
Reports of commercial use	50
Inventions covered by these reports	34
Employee inventions	28
Contractor inventions	6
NEGATIVE USE REPORTS	
Reports of no commercial use	88
Inventions covered by these reports	56
Employee inventions	40
Contractor inventions	16

EXCLUSIVE LICENSES

EXCLUSIVE LICENSES GRANTED TO DATE	21
Employee inventions	14
Contractor inventions	7
POSITIVE USE REPORTS	
Reports of commercial use	6
Employee inventions	4
Contractor inventions	2
NEGATIVE USE REPORTS	
Reports of no commercial use	15
Employee inventions	10
Contractor inventions	5

* See Appendix B

Appendix F

COMPARISON OF NASA INVENTION COMMERCIALIZATION STATISTICS
(Five past studies)

Study	# of inventions waived	# commercialized (%)	# of inventions licensed (# of licenses)	# commercialized (%)
Robert Solo [13] 1966	160	7 (4.4%)	48 (118)	1 (2.1%)
Watson & Homan [14] 1966	189	21 (11%)	47 (108)	5 (10.6%)
Phillip Wright [15] 1974	668	97 (14.5%)	- -	- -
Kaskovich [16] 1974	333	52 (13.5%)	? (226)	60 (>26.5%)
NASA [17] 1979	1046	193 (18.5%	- -	- -

Appendix G

PERSONAL INTERVIEWS CONDUCTED

In order to gain a better perspective on industry's views OF NASA's patent policy, personal interviews were conducted with the owners of several small firms and patent attorneys from several medium and large firms that have performed NASA research in the past. Interviews with the patent counsels from eight Federal agencies (NASA, DOE, DOD, USDA, HEW, DOI, NSF, DOT), the Office of Federal Procurement Policy (OFPP), the American Patent Lawyers Association, Research Corporation, and numerous industry associations were also conducted.

These interviews proved invaluable in providing insight into the industry and Government views of alternative Government patent policies. Findings from these interviews have been included in the report where relevant.

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COSMIC AND THE MARKET FOR COMMERCIAL SOFTWARE

Mark Matousek
April 1981

Abstract

The Computer Software Management and Information Center (COSMIC) is a clearinghouse for over 1500 computer programs developed during the course of NASA and DOD research. The first part of this paper outlines the changes occurring in the supply of and demand for computer software, reviews the size and make-up of the marketplace and also examines the trends that will shape the market in the '80s.

The second part of the paper addresses the criteria that determine whether a user will develop the software in-house or purchase it from an external supplier.

COSMIC offers a wide selection of software with a relatively low purchase price. But it is important to note that the purchase price is only a small fraction of the software's total life cycle cost. Other costs resulting from integrating, modifying or maintaining a COSMIC program may be substantially higher than those of alternative systems. COSMIC customers also face greater uncertainty regarding the program's exact capabilities, and this uncertainty inhibits transfer.

COSMIC and the Market for Commercial Software

Mark Matousek

REPORT NO. 32

April 1981

National Aeronautics and Space Administration
Contract NASW 3204

PROGRAM IN INFORMATION POLICY

Engineering-Economic Systems Department
Stanford University Stanford, California 94305

1. INTRODUCTION

The Computer Software Management and Information Center (COSMIC) is a clearinghouse for over 1500 computer programs developed during the course of NASA and DOD research. Since COSMIC was established in 1966 the supply of and demand for computer software have changed substantially. Demand for software has outpaced the ability of in-house programmers to meet demand effectively leading to the rapid growth of both custom design and packaged software suppliers whose sales have recently exceeded $1.4 billion and $1.2 billion respectively [STAF80].

COSMIC is thus in the enviable position of being a supplier of a scarce commodity in a rapidly expanding market. COSMIC's ability to participate in the rapid growth of packaged software sales will be enhanced by an awareness of the software market, especially the needs of software users.

The first part of this paper outlines the changes occurring in the supply of and demand for computer software, reviews the size and makeup of the marketplace and also examines the trends that will shape the market in the '80's. From this analysis it is apparent that COSMIC has a unique position in the software market. It has a large supply of previously developed software and it supplies software in a manner considerably different than most commercial software suppliers.

The second part of the paper addresses the criteria that determine whether a user will develop the software inhouse or purchase it from an external supplier. The primary criteria used to predict software acquisition decisions are firms' goals to minimize both the software's total life cycle cost and the uncertainty that the software will possess all of the desired capabilities, will be acquired within budget or within the desired time period.

It appears that from the viewpoint of a potential software buyer COSMIC offers a wide selection of software with a relatively low purchase price. But it is important to note that the purchase price is only a small fraction of the software's total life cycle cost and although the purchase price is lower, other costs resulting from integrating, modifying or maintaining a COSMIC program may be substantially higher than those of alternative systems. COSMIC customers also face greater uncertainty regarding the program's exact capabilities compared to many internally developed programs or widely used commercial packages.

2. PART I -- A MARKET OVERVIEW OF COMPUTER SOFTWARE

The present market for computer software is changing so quickly that it may be best initially described by the trends that have presently shaped it and will shape it in the near future.

1. demand for an ever widening variety of computer services is increasing each year (see figures 1 and 2)

2. hardware capabilities have increased rapidly and should continue to far outstrip any increases in cost [PHIS75],[DENI79]

3. software programming capabilities have not improved substantially and no breakthroughs in language efficiency, standardization or abilities are expected in the near future [FRAN79]

4. software costs are increasing each year due to:

   a) shortages of system engineers and programmers

   b) increasing salaries for the above [FRAN79]

5. users are annually increasing their expenditures on software (see figure 1)

6. users are buying an increasing percentage of their software instead of developing it in-house [STAF80]

7. suppliers of proprietary software are a diverse, fragmented and highly competitive group providing an equally diverse range of services [DATA78]

8. an increasing number of vendors are providing extensive training and support during and after installation [DATA78]

Software sales have recently surpassed $2 billion although it is difficult to formulate accurate estimates of sales because not only are software suppliers rapidly appearing and disappearing but they tend to consider sales figures proprietary information [PHIS75]. It must be realized that these resources are only a small part of the total resources that are annually used in developing software. Estimates of internal expenditures on software reach as high as $200 billion per year [ROAC75]. But it is the increasing sales of packaged software that most directly effects COSMIC since this is the segment of the market in which COSMIC must make all of its sales.

The current number of software packages available is estimated to be about 3000 to 4000 packages [DATA78] excluding the more than 1500 programs offered by COSMIC alone. This shows that most suppliers are highly selective in the programs that they offer for sale, by and large offering very few per company. By far the largest supplier of commercial software packages is IBM offering approximately 800 [DATA78].

These figures illustrate that the marketing strategy employed by most commercial suppliers is very different than the "shotgun approach" being used by NASA.

Current estimates of the present growth rate in annual sales varies from 20% to 30%. Past growth has recently averaged about 25% to 28% per year. The growth in total invoiced sales by COSMIC has closely followed the overall growth of the packaged software market except for declining COSMIC sales in 1972, 1974 and 1975 (figure 1). COSMIC sales presently account for about 0.25% of total packaged software sales.

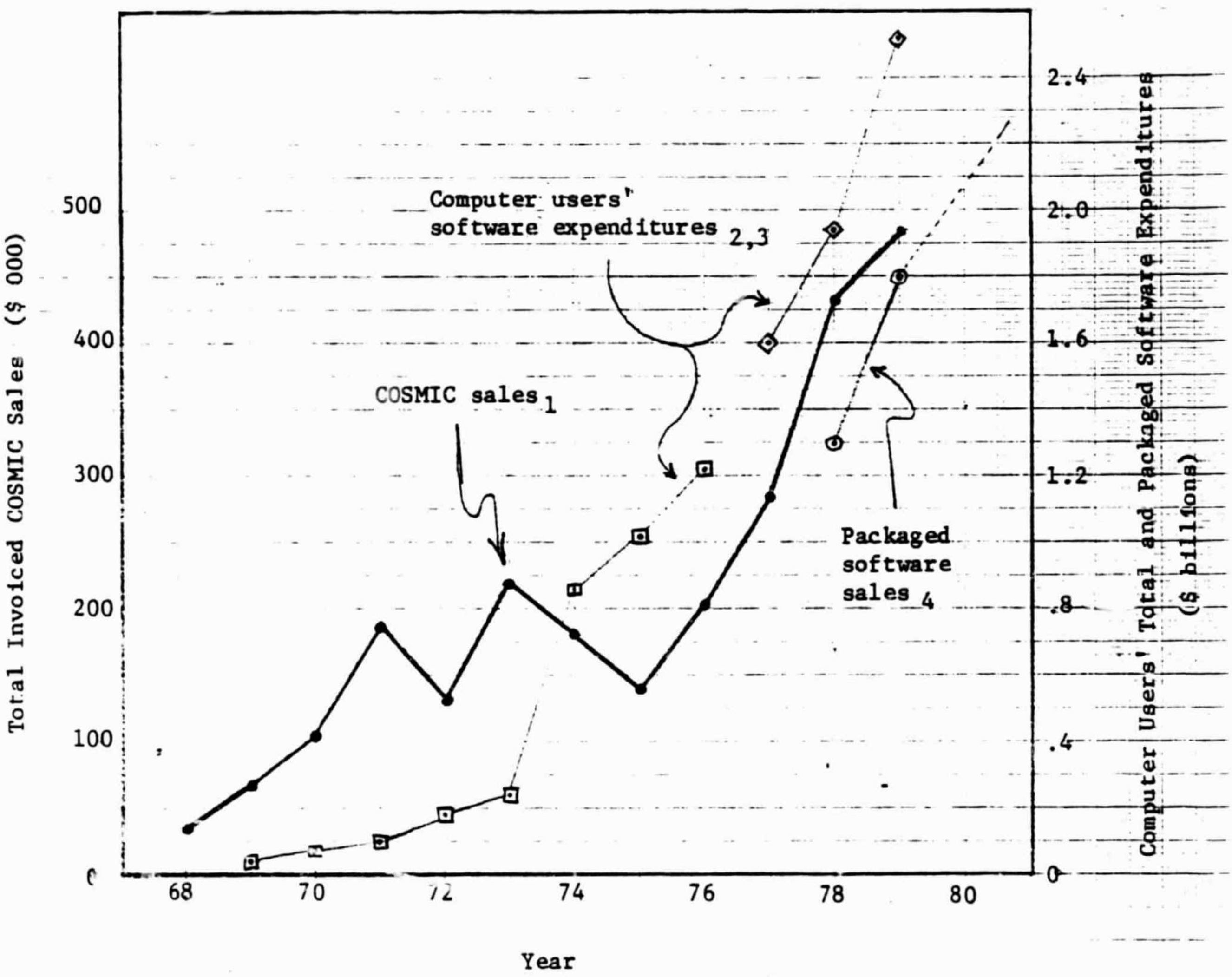
The projected growth rate for the components of packaged software indicate that sales of applications software is the largest and fastest growing component followed by utility software and systems software (figure 2). This trend is especially important to COSMIC because most of the COSMIC programs are applications oriented.

One change that has had a major effect on the software market is the rapid increase in the cost of software in comparison to the cost of hardware. As a result, expenditures on software have increased from less than 20% of total expenditures on hardware and software to nearly 70% in 1980 (Figure 3). This change has made expenditures on software much more visible and increased the demand for efficent and useful software.

The present shortage of well trained systems engineers and programmers has also made it more difficult for many companies to maintain an in-house staff capable of meeting the demands for better software. As a result, proprietary software packages have become an increasingly profitable business [FRAN79].

There are several factors that determine whether software will be developed in-house or purchased outside. Most software suppliers claim that the most important advantage to proprietery software is that its total cost to the user is significantly less, oftentimes one third or one fourth the cost of in-house development. Since many suppliers now provide extensive support during and after installation, there are a number of places where costs are reduced. In

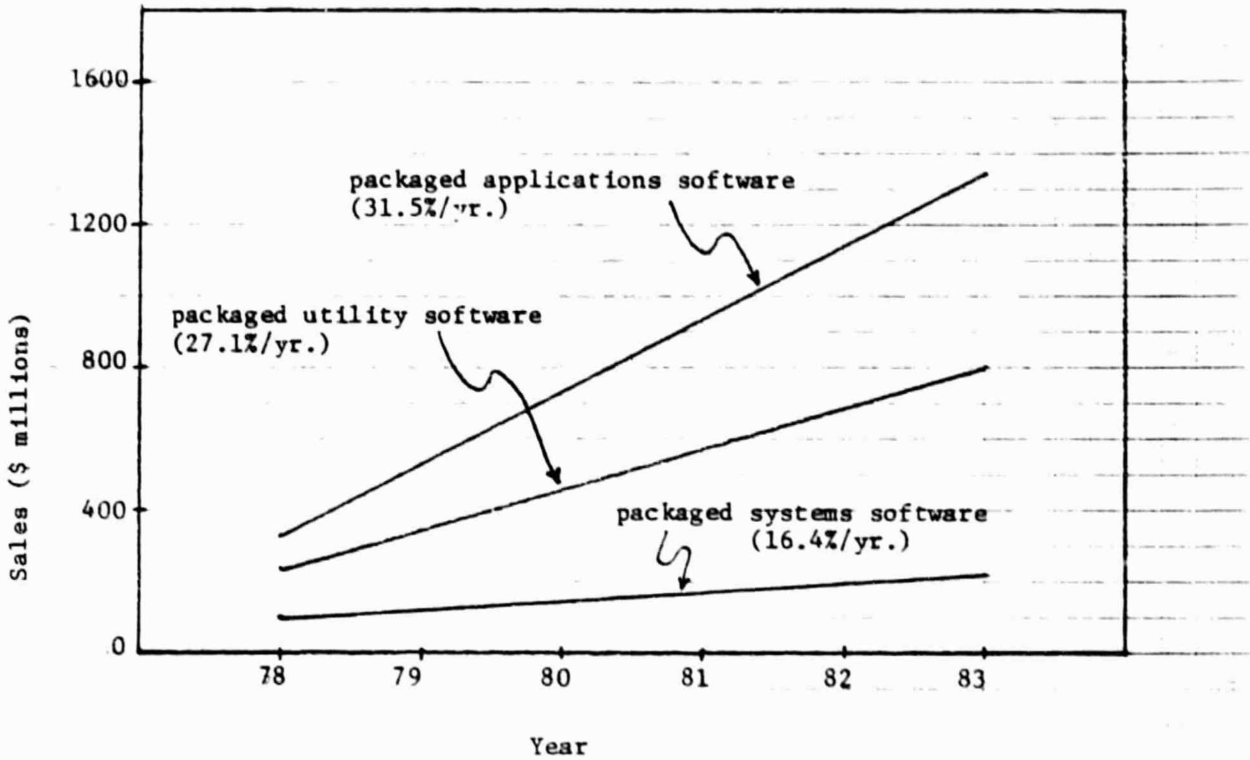
Figure 1: Comparison of COSMIC Sales to External Software Expenditures



1 - COSMIC Annual Report 1979
2 - EDP Reports 2/23/79
3 - Predicasts Basebook 1979
4 - EDP Reports 2/23/79

many cases the cost of the software will include installation, debugging, user training, program maintenance, and even enhancement of the the program if the supplier

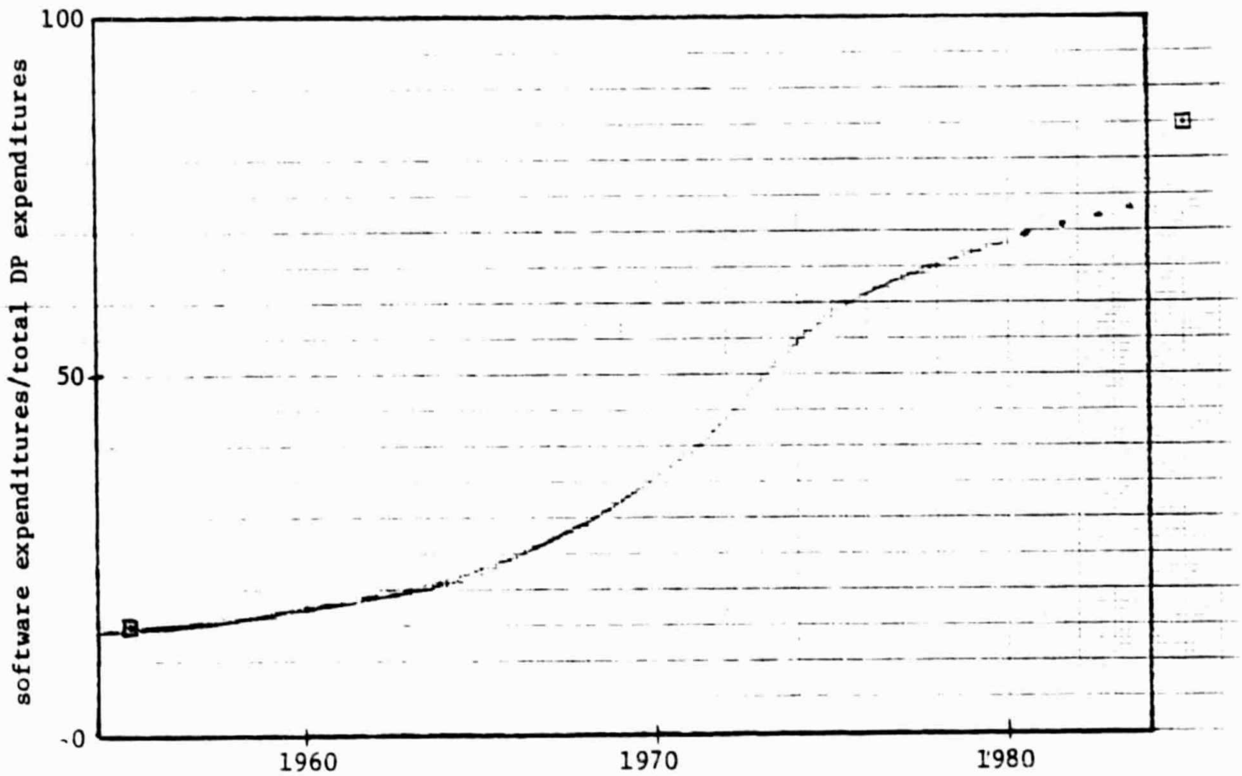
Figure 2: Projected Growth of the Components of Packaged Software Sales



develops an improved program. The use of proprietary software also allows a smaller in-house programming staff. Suppliers also claim that the average quality of their packages is superior to most in-house programs, resulting in better documentation, programs that are more efficent and easy t use and also have greater certainty in their capabilities.

There is, at least in theory, some economic justification for these claims made by commercial software suppliers since the development costs of commercial programs may be divided among a multitude of users, therefore justifying higher development expenditures. It has been estimated that 70-90% of the programs written all over the world are functional duplicates, developed at a cost of between $280-360 billion [GORD75]. As a result, programs commercially available have tended to be large programs with broad applicability, having both high development costs and high market demand. This trend can be seen in the rapid increases in the sales of large and costly database management systems, payroll systems or inventory systems. Capabilities beyond those of most general purpose products tend to be suspect by potential users because such additions "could well end up being the most costly or discretionary elements" [FRAN79].

Figure 3: U.S. Software Spending as a Percentage of Total DP Spending



The advantages of package software are obviously highly dependent upon the quality of the packaged software and the programming ability of the user's staff. A potential buyer must not only assess the program's purchase price but also the shopping, training, installation and maintenance costs as well as the willingness of the user's staff to use a program "invented elsewhere". Part II examines these costs and benefits in greater detail.

For these and a number of other reasons, there are now a wide variety of suppliers of software. As previously mentioned the largest source is still in-house staffs, but the other sources of software are:

1. computer manufacturers - most mainframe manufactures sell a variety of systems and applications packages for use on their computers. IBM now offers more than 800 such packages.

2. software houses - these suppliers as a group provide package software for a wide variety of uses, while some also provide custom software written for specific users. Most "houses" are small and specialize in certain types of programs and provide fairly extensive vendor support with only a few large houses offering a broad selection of programs.

3. software brokers - these brokers as their name implies match user needs to specific programs, often developed elsewhere.

4. clearinghouses - COSMIC and a small number of similar services offer programs developed for specific in-house tasks for sale for relatively low prices with little or no vendor support.

5. software users - similar to the clearinghouses, many users who have developed sophisticated software packages for their own use then sell the package to other users to recoup at least part of the development cost.

6. turnkey suppliers - several companies provide total custom computer systems including all hardware, software user training, installation, debugging and most of the program maintenance.

7. computer stores - many computer retailers also now offer software packages for many of the types of computers they sell.

All of these types of suppliers except the clearinghouses and the computer stores appear to be providing an increasing level of vendor support. A survey conducted by Datapro in 1978 of eighteen suppliers whose packages have received widespead user acclaim showed that those vendors saw post-installation support as the most important criteria in gaining and maintaining users. Next in order of importance were ongoing enhancement, good documentation, installation support, and customer training (table 1).

TABLE 1

Factors Affecting User Support of Commercial Software

	1976	1977
post-installation support	3.41	4.22
ongoing enhancement	2.91	3.67
quality documentation	3.77	3.51
installation support	3.23	3.44
user training	4.00	2.82

(rated on increasing importance from 1 to 7)

3. COSMIC'S PRESENT SERVICES

The services that COSMIC offers are very different than almost any other supplier of software. Most suppliers are for profit companies that offer a small number of programs with a high level of vendor support. NASA has chosen a different strategy, offering a vast number of programs with very little vendor support. COSMIC provides documentation for its programs although that too must be purchased separately. No other vendor support is provided except the names of the program's developer or other users.

The programs provided by COSMIC appear to cost significantly less than comparable programs provided by suppliers. COSMIC's programs are sold on the basis of trying to recover as large a portion of COSMIC's operating expenses as possible. Traditionally NASA has provided about one third of COSMIC's operating expenses. The operating expenses rarely include any of the program's development costs.

It is difficult to assess the effects of COSMIC's policies upon potential users. By and large COSMIC does not seem to be well known within the industry. Of the six software brokers that were contacted to date in a survey being conducted by the author, only one employee at Datapro was familiar with COSMIC. His familiarity was limited to the twenty-seven COSMIC programs listed in the Datapro Directory of Software and the comments of the two NASTRAN users that responded to a Datapro survey.

The comments of the those two users gave the NASTRAN program (COSMIC's most used program) ratings of "fair" for overall user satisfaction, program efficency, ease of installation, ease of use, and documentation and a rating of "poor" for vendor support. The program was also viewed as inflexible, costly, relatively complex, slow, using excessive resources, lacking key capabilities and having compatability problems. This sample size is so small that no solid conclusions can be made.

4. PART II -- IN-HOUSE VS. PURCHASED SOFTWARE

The user's decision to develop needed software in-house or to purchase it from an outside supplier has been given little study although a rapidly increasing number of users are having to make this decision due to the increasing cost of programming in-house. Although annual sales by software suppliers have passed $2 billion, few authors have examined the factors that underlie this "make or buy" decision.

This chapter examines two of the most important factors underlying this decision; the programs life cycle cost and the risk that it will not fulfill the user's requirements. These factors are examined for four acquisition alternatives:

1. in-house development,

2. purchase from a clearinghouse (such as COSMIC),

3. purchase of a "turn-key" system, and

4. purchase from a software house (limited vendor support).

This information should prove useful for the managers of COSMIC in understanding the dynamics of the present software market.

4.1 SOFTWARE LIFE CYCLE COSTS

Estimates of the cost of software development have historically accounted for only a fraction of the total software development life cycle costs [ZELK78]. Software maintenance costs, which were not included in many previous estimates, account for approximately 50% to 75% of the total software development lifecycle costs [FRAN79],[PUTN77], [ZELK78]. The term maintenance encompasses a number of different activities including operational debugging, program modification, user training, revision of documentation and program management.

Figures 4 and 5 show two approximations of the costs of the different stages of software development when maintenance costs are not included. (NOTE - Because there are no obvious divisions between the steps in software development, no common breakdown of the steps in the development process has arisen. The differences in both the terms defining the stages of software development and the activities included in these stages is obvious when figure 4 and 5 are compared. This paper uses the seven step process defined in Zelkowitz,

shown in figures 6 and 7 and consisting of requirements, specifications, design, coding, testing, integration and maintenance).

Figure 4: Software Development Costs (After [ZELK78])

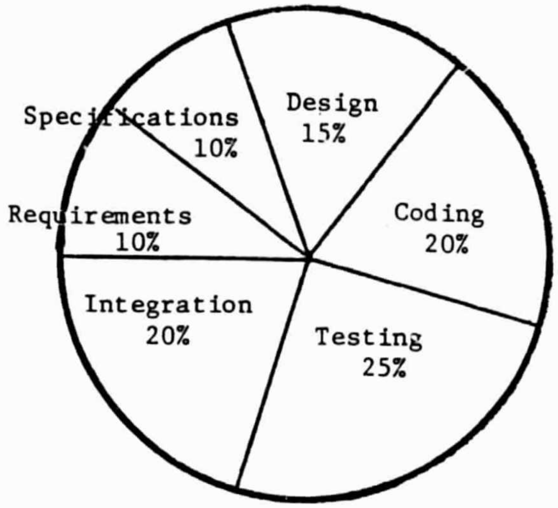


Figure 5: Software Development Costs (After [WOLV74])

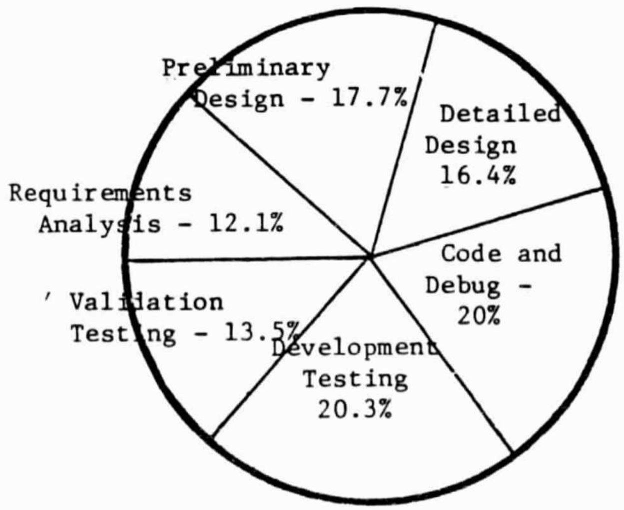
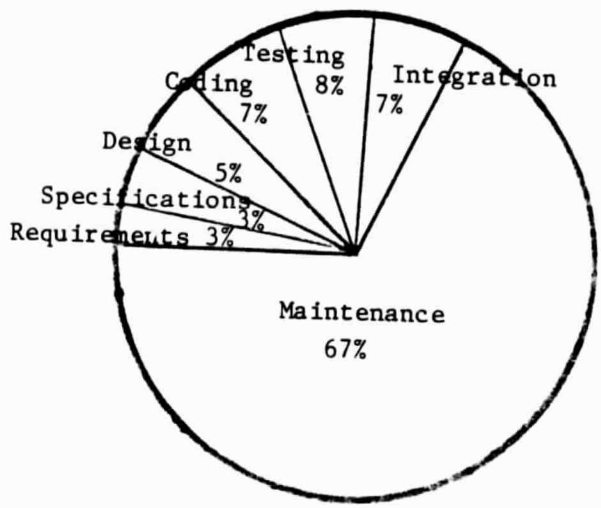


Figure 6 shows that when the overall life cycle costs are examined, the initial development costs are dwarfed by the maintenance costs. Even if the present value of these costs are examined instead of the costs in constant dollars, total life cycle costs are still dominated by maintenance costs.

Figure 6: Software Life Cycle Costs (after [ZELK78])



This result is crucial to this examination of the services offered by COSMIC because the maintenance costs that COSMIC customers must bear will in general be considerably higher than similar costs for other available software. This is due to the fact that almost all of the programs in the COSMIC library were developed to fulfill specific NASA needs and many of the programs therefore require extensive program modification, user training, debugging and revision of documentation in order to meet users' needs. COSMIC also provides little if any vendor support compared to most other software suppliers and therefore the user must bare the full costs of program integration and maintenance. The vendor support provided by COSMIC is limited to facilitating contact between the user and the program's developer on all programs and providing some user training, system integration and program enhancement for the NASTRAN program alone.

The following economic model illustrates the type of costs that a software user faces and shows how program integration and maintenance costs are oftentimes the most important criteria in deciding the means of software acquisition.

As previously mentioned, software may not only be developed in-house, it may be purchased from a variety of suppliers. The type and approximate magnitude of the costs associated with software development are modeled for four different means of acquisition:

-in-house development,
-purchase of a "clearinghouse package",
-purchase of a "turn key package", and
-purchase of a "limited support package".

These four sources span the range of the means of software acquisition and illustrate the different types of costs facing the prospective user.

The cost of acquiring software may be broken down into seven approximately sequential parts. Initially the decision must be made that new software is needed and broad requirements that outline how the software will be used must be defined. This activity incurs cost c(r). The ensuing steps and their respective costs are listed below. Program specifications are then written - c(s). The total system is then designed - c(d), followed by the coding of the program - c(c). Once coded the program may then be tested to ensure that it meets its specifications - c(t). The program can then be integrated with the hardware and software necessary for the program's use - c(i). Finally the software program must be maintained - c(m).

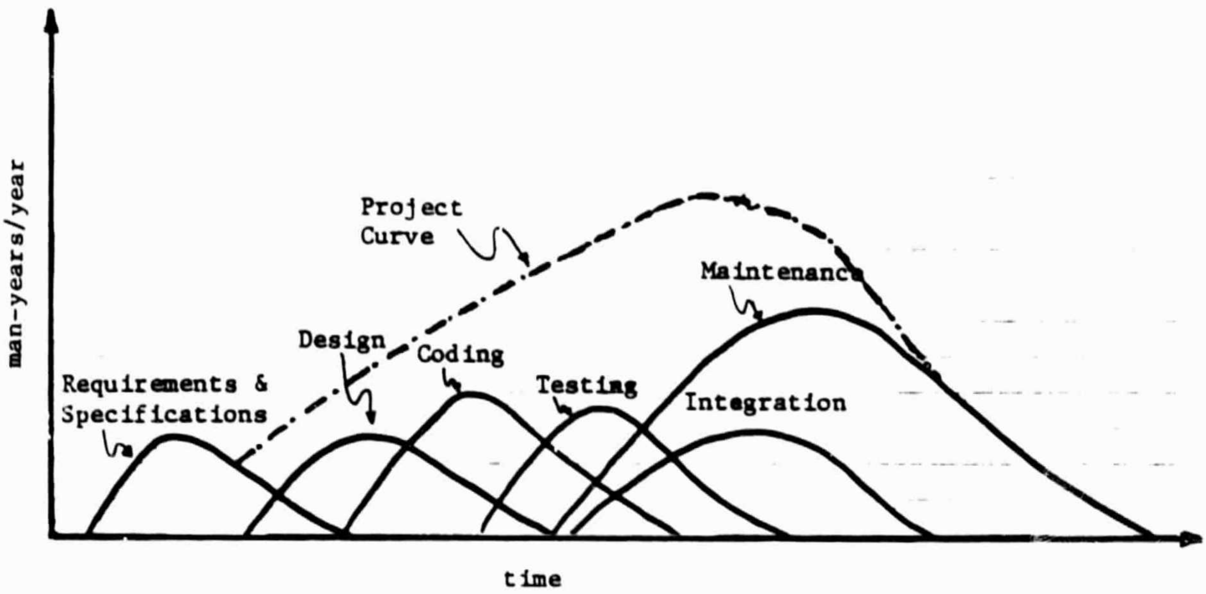
The total life cycle cost of acquisition of the software to the user is:

$$LCC = c(r)+c(s)+c(d)+c(c)+c(t)+c(i)+c(m) \qquad \text{(eq. 1)}$$

If the software is purchased instead of developed in-house a selection cost will be incurred - c(se) in addition to the package's purchase price - c(p). But now, the user will not have to pay all of the costs in equation (1) since some of those costs will be absorbed in part by the vendor of the software. The quality of the software and the level of vendor support wil. determine which costs the user will not have to pay.

It should be noted that the stages in a program's development and use overlap and are difficult to clearly define and as a result almost every case study of software development has defined these steps or activities differently. But it has been shown that the rate of expenditure on each of these activities can be approximated by a Rayleigh curve [PUTN77], although this approximation has been claimed by some to be a poor representation of the actual input of programmer effort. This more exact representation of the costs of software development originally shown in figure 5 is represented in figure 7.

Figure 7: Software Development Costs per Year [PUTN77]

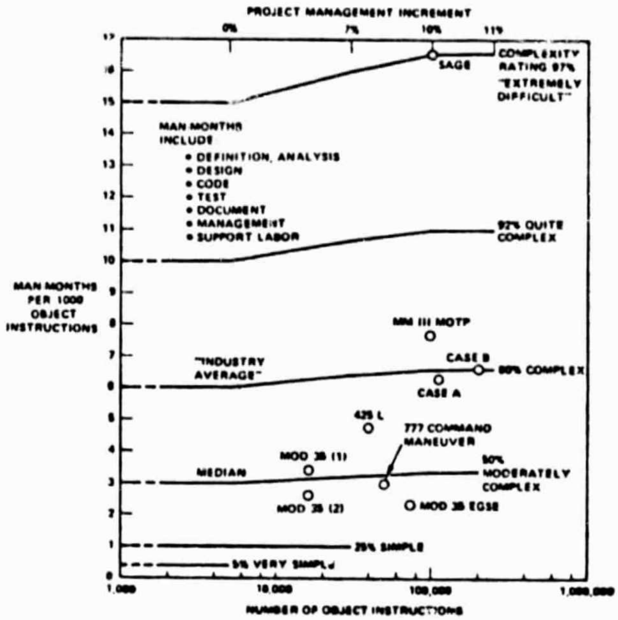


In the model, we assess the acquisition of an applications program consisting of 10,000 source statements. This is the approximate size and nature of many of the larger programs in the COSMIC library (see Appendix B for a breakdown of the average size and price of the programs listed in "COSMIC - A Catalog of Selected Programs"). The program's development cost depends upon a number of factors including program complexity, programmer experience, etc. Metzelaar has estimated that tne number of man-years required to develop a program of this size can vary from about 0.4 man-years for a very simple program to over 13 man-years for an extremely difficult program. The "industry average" for a program of this size is about 5 man-years (see figure 8).

These life cycle costs for in-house development are graphed in figure 9 as they accumulate over time. We assume that the program will have an initial development time of one calendar year and a useful life of five years with 75% of the maintenance costs occurring during the first year of operation and the other 25% being distributed evenly during the remaining four years. If the present value of these costs is calculated using a discount rate of 15%/year, maintenance costs decline from 67% of the program's total life cycle cost to 61%.

This graph clearly shows that the cost of maintaining software should be a primary concern to the potential software user.

Figure 8: Programmer Productivity [WOLV74]



The life cycle costs associated with the purchase of a "clearinghouse system" such as those supplied by COSMIC are somewhat different than those associated with in-house development. These costs may be broken down into five categories - requirements, selection, purchase, integration and maintenance.

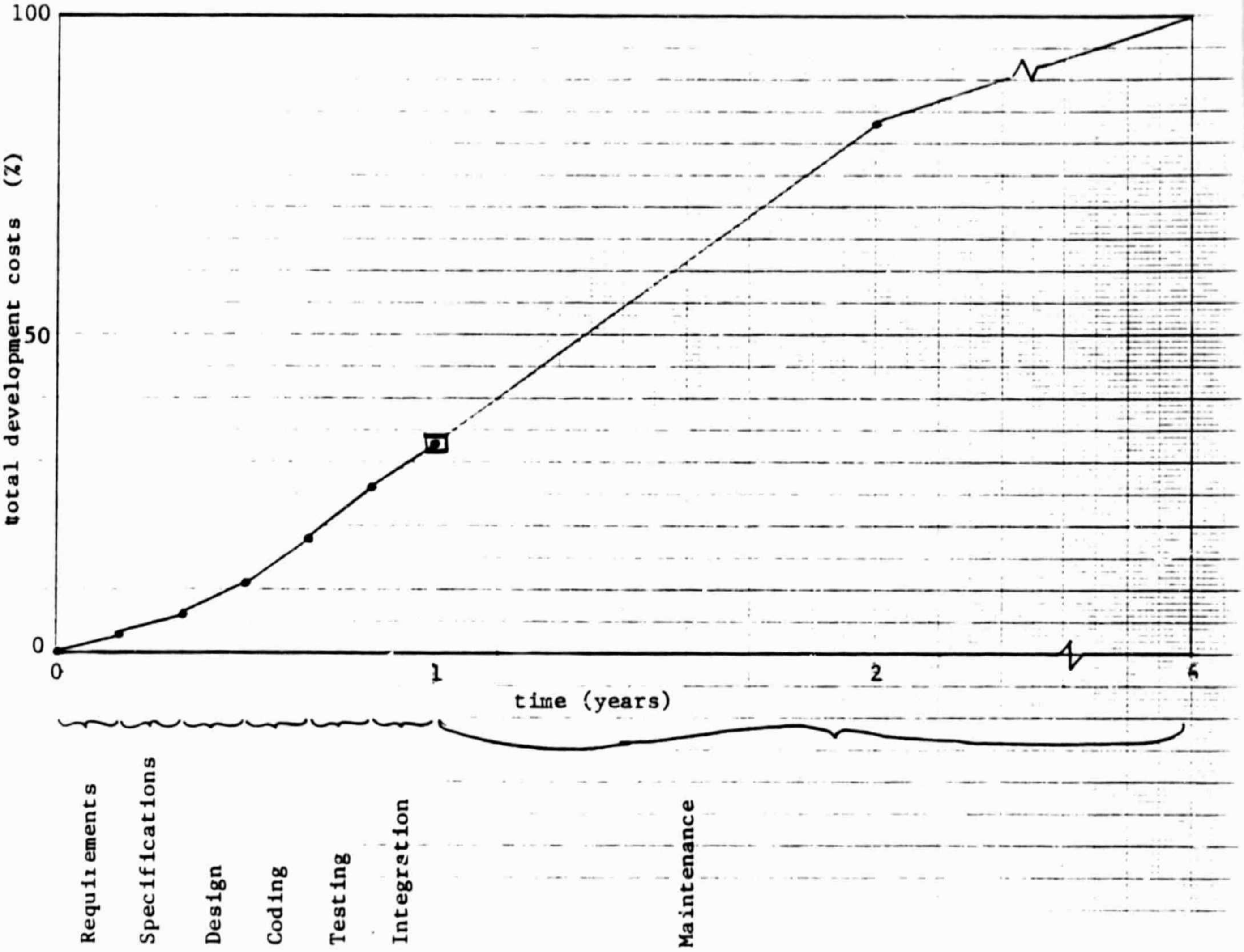
LCC = c(r) + c(se) + c(p) + c(i) + c(m)   (eq. 2)

The selection cost - c(se) - is essentially a shopping cost and includes the cost of identifying and comparing suitable programs. This cost is assumed to be roughly comparable in amount to that of defining the program's requirements, or about 3% of the program's total life cycle costs.

The purchase price for a 10,000 source statement program from COSMIC ranges from about $400 to $2000 [NASA]. If an intermediate cost of $1000 is assumed then for a program having a total life cycle cost of $600,000 as was the case in the previous example, the purchase price constitutes only 0.16% of the total life cycle cost. Because the purchase price of most COSMIC programs is such a small percentage of the total life cycle cost facing the programs' users, the demand for COSMIC programs should be insensitive to even major changes in the prices charged for the programs (price elasticity of demand is approximately equal to zero).

The cost of integrating the COSMIC program with the user's computer system is likely to be much higher than the

Figure 9: Life Cycle Costs of In-House Software Development

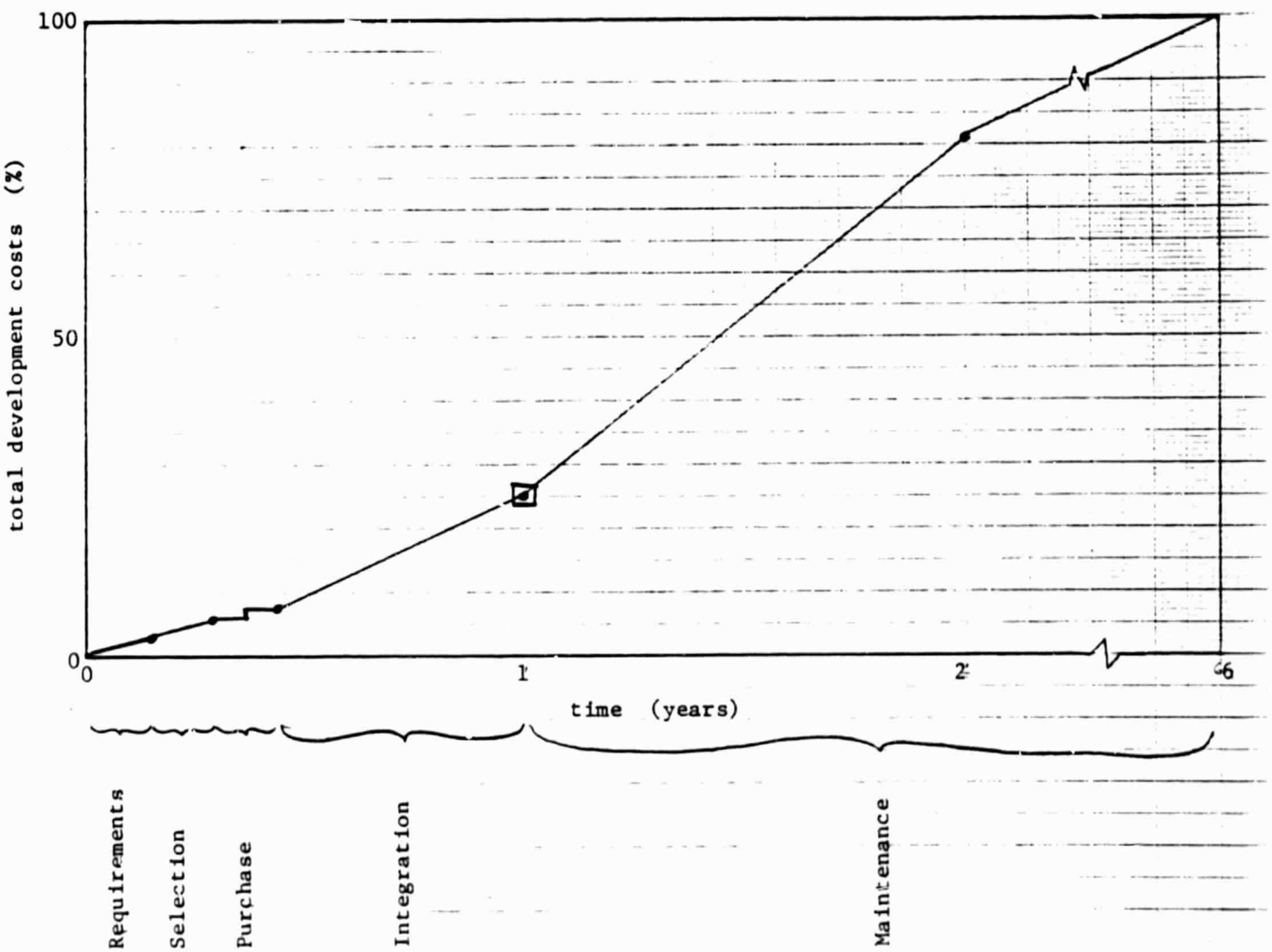


7% estimate for in-house development. This increase is due to the program not being initially developed to be used on the user's computer system or to fulfill the user's specific needs. Therefore for most COSMIC programs considerable adaptation is necessary in order for the program to interface satisfactorily with the user's existing hardware and software systems. This high cost of program integration can be observed in the $17,424 and $32,292 spent in two unsuccessful attempts to install COSMIC programs or in the $50,000 fee that a cosulting firm charges to install NASTRAN [HENT79].

Figure 10 shows a breakdown of the life cycle costs faced by a user of a COSMIC program where the intergration

cost has increased to 18% of the total and the maintenance cost has increased to 75% of the total. The increase in the maintenance cost is due to the increased level of user training, debugging and revision of documentation necessary for the satisfactory use of a COSMIC program. It should also be noted that any bugs not detected by NASA during a program's development become increasingly expensive for a user to fix. An error costing $1000 to fix during coding will cost about $10,000 to fix during operation [PHIS79].

Figure 10: Life Cycle Costs of a Purchased (Clearinghouse) Program



Comparing the life cycle costs of in-house development against those of a clearinghouse system indicate that a potential user should purchase a clearinghouse system when its associated costs of selection, purchase, integration and maintenance are less than the in-house system's specifications, design, coding, testing, integration and maintenance costs.

The third alternative means for a software user to obtain a program is to purchase a "turn-key system". A turn-key system is one in which the vendor provides not only the program's source code and documentation like COSMIC but also provides extensive vendor support including program adaptation, installation, testing, debugging, user training and periodic program enhancement. As figure 11 shows, the overwhelming majority of the program's life cycle cost is due to the program's purchase price. The only other costs that the user faces arre those due to requirements, selection and a percentage of the maintenance cost.

The differences between the purchase of a "turn-key system" and the purchase of a "clearinghouse package" on the user's cost stream and number of in-house personnel required are significant. Use of a "clearinghouse package" tends to result in a smoother outflow of capital but also requires a larger in-house programming staff than does a use of a "turn-key system".

There are many suppliers of software packages who provide vendor support which is not nearly as extensive as that of some "turn-key" suppliers but much more comprehensive than that provided by COSMIC. Figure 12 illustrates a possible life cycle costs associated with such a program.

Figure 11: Life Cycle Cost of Turn-Key Purchased Software

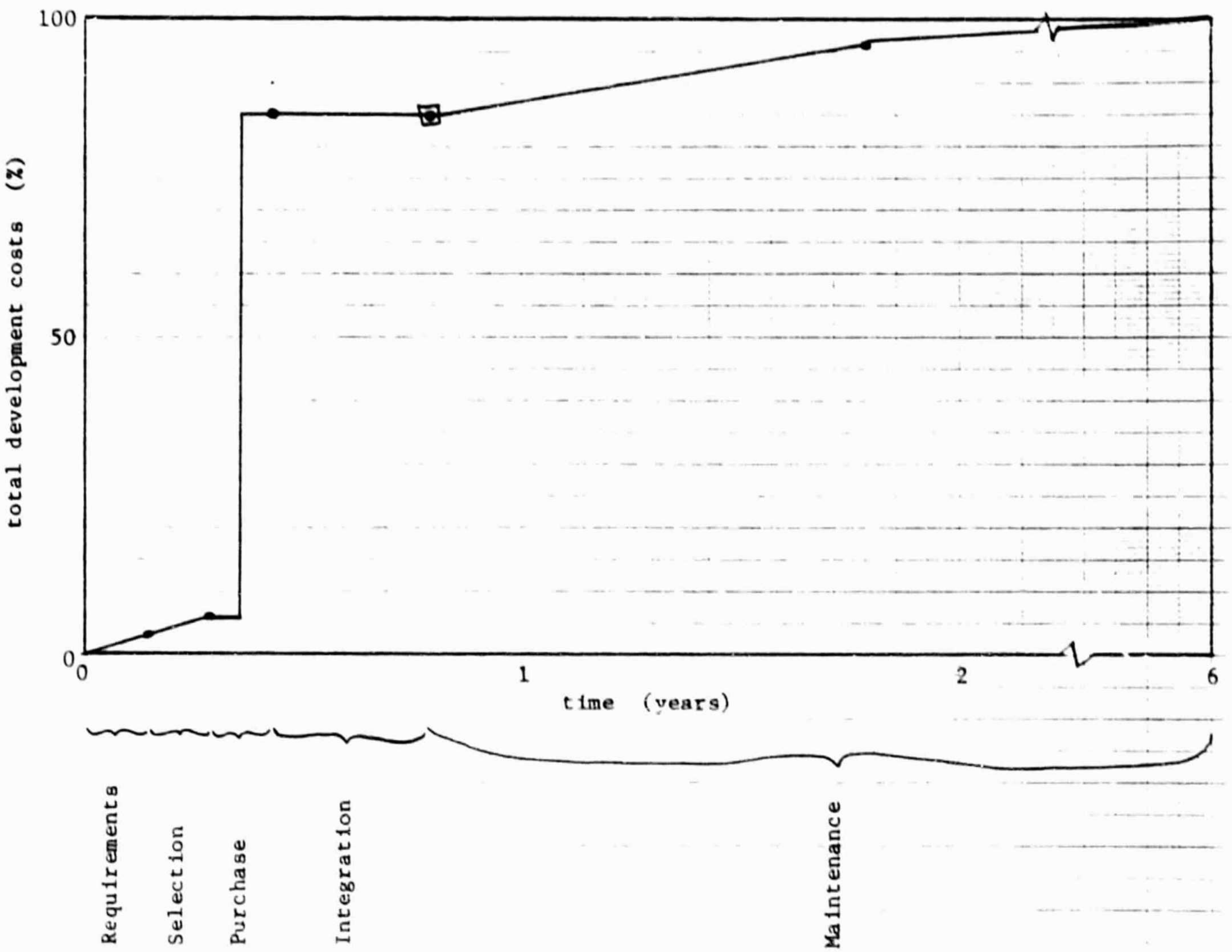
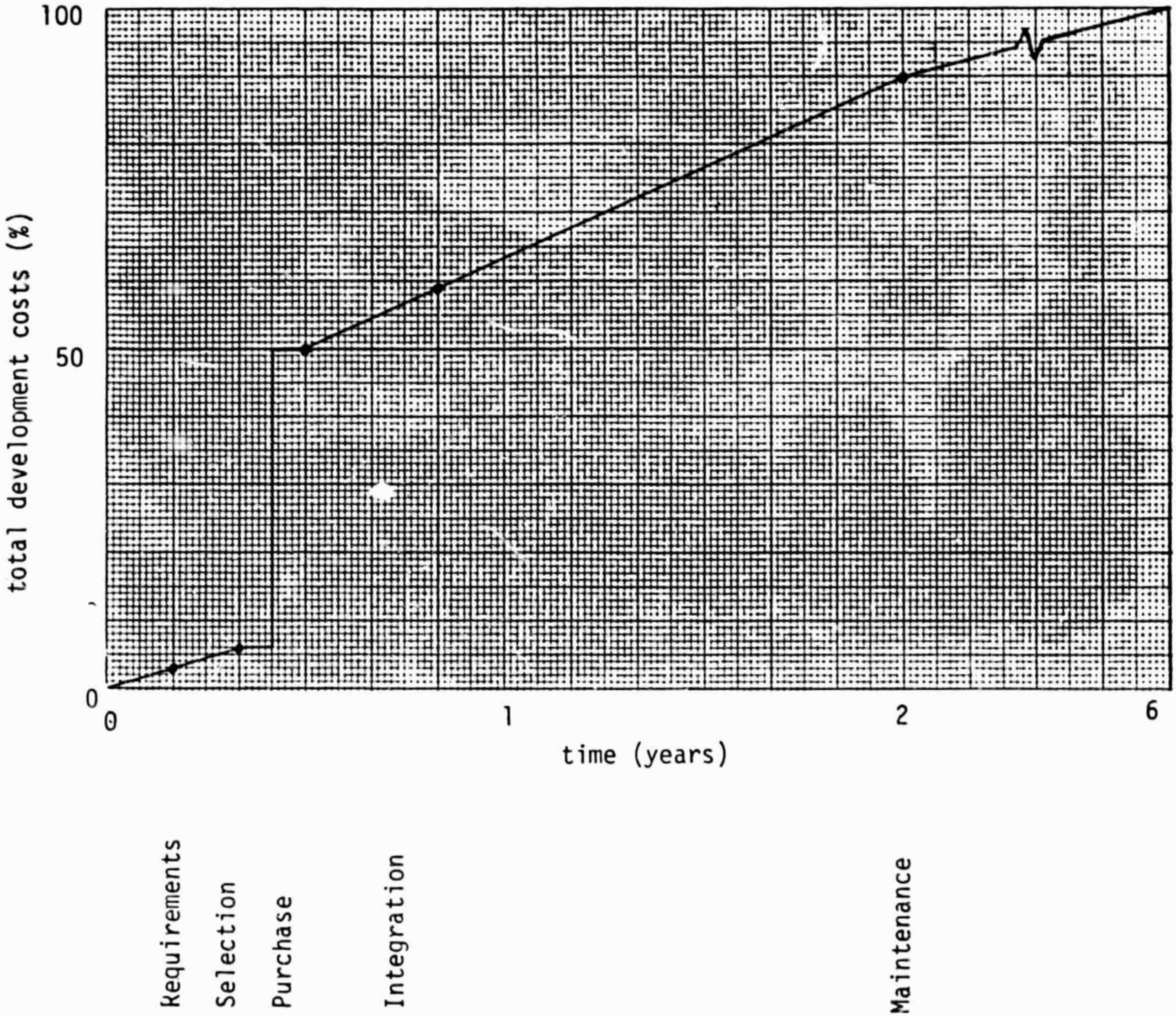


Figure 12: Life Cycle Cost of Software with Limited Support



4.2 UNCERTAINTY IN SOFTWARE ACQUISITION

Software users' acquisition strategies can be better understood if we assume that their strategies are strongly influenced by a desire to minimize the uncertainty involved in using software. This improved ability to predict software users' decisions could be very useful to COSMIC in increasing the marketability of COSMIC's software programs. Therefore, this section compares the relative uncertainties inherent in the four software acquisition alternatives described in section 4.1.

In software acquisition, there are three major uncertain elements:

- the software's life cycle cost,

- the software's capabilities, and

- the date the software will be ready for use.

There is greater uncertainty in these three areas in software development than there would be in most similar engineering development projects because software development is still a poorly understood and unpredictable process. Large cost overruns, missed completion dates and even complete project failures are not uncommon in software development. For this reason, the relative uncertainties in these three areas become of even greater importance to potential users comparing alternative software products.

The assumption that software users attempt to minimize the associated risks and uncertainties stems from the well documented risk aversion of most corporate decisionmakers. Past studies have shown that although risk attitudes vary significantly within organizations [SWAL 66], few if any corporate decision makers are risk-preferring (i.e., willing to support projects with negative expected values) [SPET 68]. It has also been shown that as the uncertainty of a project's profitability increases, the project's subjective utility decreases. One way this uncertainty can be visualized is by plotting the probability distribution of the present value of a project. As an example, figures 13 and 14 show two possible probability distributions of the present value of two software acquisition alternatives. The probability distribution in the second figure is much flatter indicating greater uncertainty in the present value predictions.

Although the two projects have the same expected value ($1 million), studies have shown that decisionmakers will assign a higher subjective utility to the first alternative. One measure of subjective utility is the certain equivalent,

Figure 13: Probability Distribution of Software Project's Present Net Worth (low uncertainty)

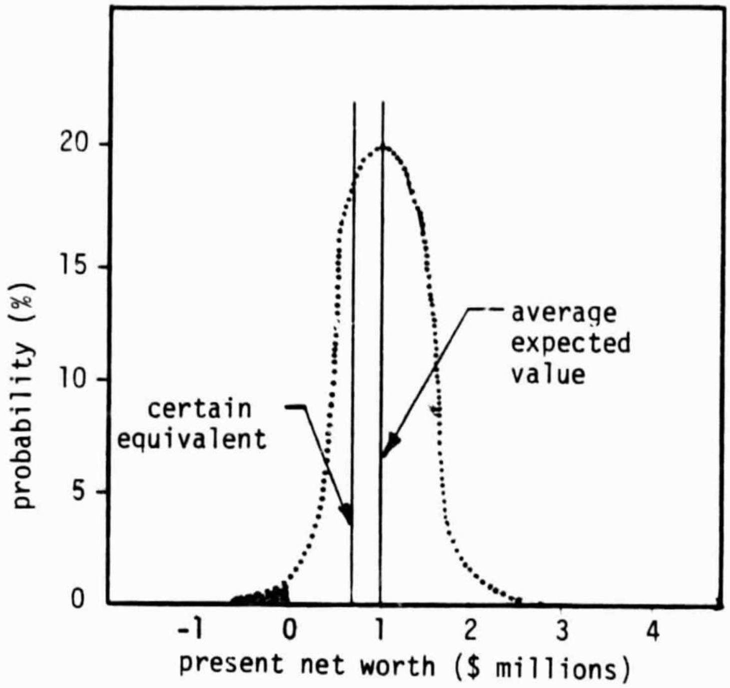
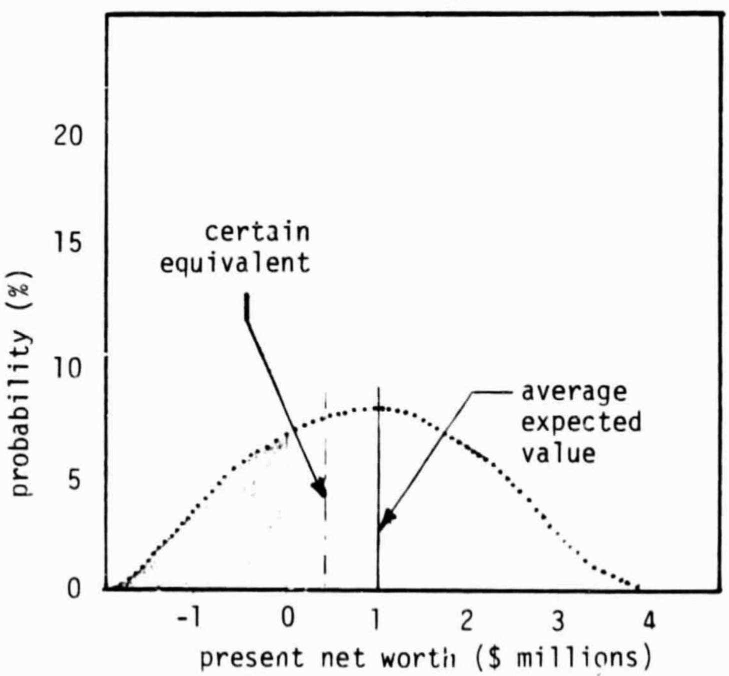


Figure 14: Probability Distribution of Software Project's Present Net Worth (high uncertainty)

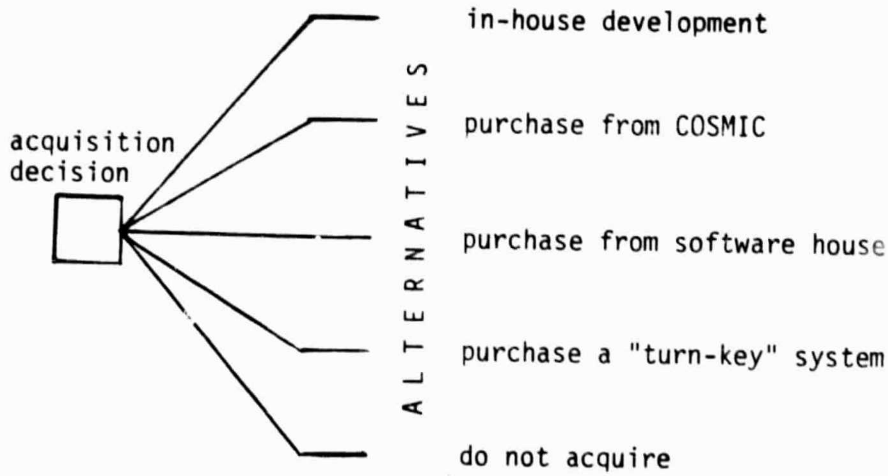


defined as the dollar value at which the decisionmaker would be indifferent between that dollar value with no uncertainty and the returns of the uncertain project. The project with the lower level of uncertainty whose returns are described by Fig. 13 will have a higher certain equivalent than the project whose returns are described by Fig. 14.

The software acquisition decision that we are examining can be modeled by the four discrete decisions described in section 4.1 where the choices span the range of the potential acquisition alternatives. This decision is illustrated by the decision tree (see Figure 15) where a fifth alternative has been included--"do not acquire" the software.

Associated with each branch of the decision are the outcomes of the software's life cycle cost, the software's capabilities and the completion date. Figure 16 illustrates how one branch of the decision tree appears when the outcomes are separated into three discrete alternatives.

Figure 15: Software Acquisition Alternatives



The three discrete outcomes are an approximation of what is actually a continuous distribution. The number of outcomes chosen would normally depend upon the decision's sensitivity to the particular outcome; the more sensitive the decision, the larger number of discrete outcomes examined.

If a decision analysis was being performed, the subjective probabilities--p_i, p_{ij}, p_{ijk}, and the values of the outcomes--v_{ijk}, would be assigned numerical values. As an example, the probabilities for the occurrence of three specific values of the in-house developed software's life-cycle cost (p_1, p_2, p_3) could be approximated as shown in Figure 17 given the decisionmaker's probability distribution. Using the same method the other probabilities shown on the decision tree could be estimated (although in our model this requires 156 probabilities). The values (V_{ijk}) shown in

Figure 16: Decision Tree for Software Acqusition

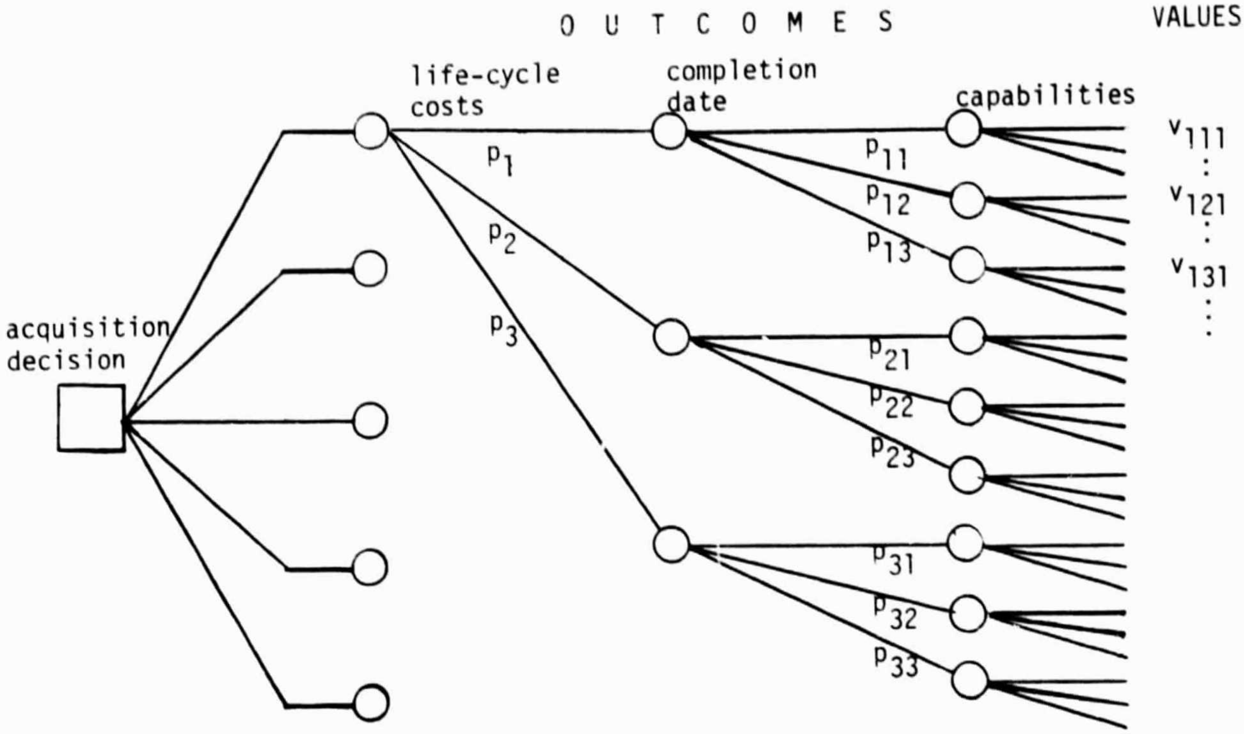


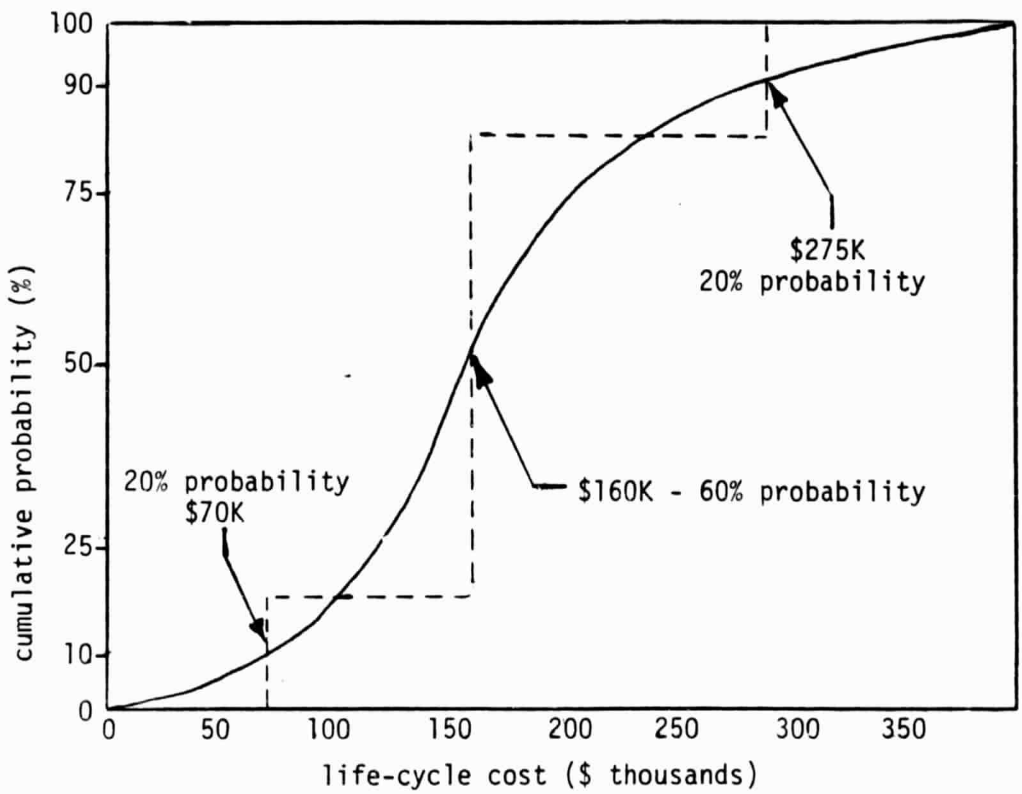
Figure 16 are the utilities assigned by the decisionmaker to each specific outcome. As an example, V_{111} would be the utility of the in-house software when the life-cycle cost is, say, \$70,000, the completion date is two years hence, and the capabilities are all those anticipated. The expected value of each alternative acquisition decison therefore equals:

$$\text{E. V.} = \sum_{k=1}^{3} \sum_{j=1}^{3} \sum_{i=1}^{3} (V_{ijk} \times p_{ijk} \times p_{ij} \times p_i).$$

If the values (e.g., v_{111}, v_{322}) are plotted against their likelihood of occurrence (e.g., $P_{111} \times P_{11} \times p_{1j}$ $P_{322} \times p_{32} \times P_3$) instead of being summed, they give a probability distribution of the expected benefits that could result from each alternative (see figure 18). Given this information and the expected value, the decisionmaker's certain equivalent can then be calculated. Since most decisionmakers are risk adverse, the greater the uncertainty indicated in the probability distribution (Figure 18), the less the alternatives certain equivalent and as a result the less likely the user will choose that alternative.

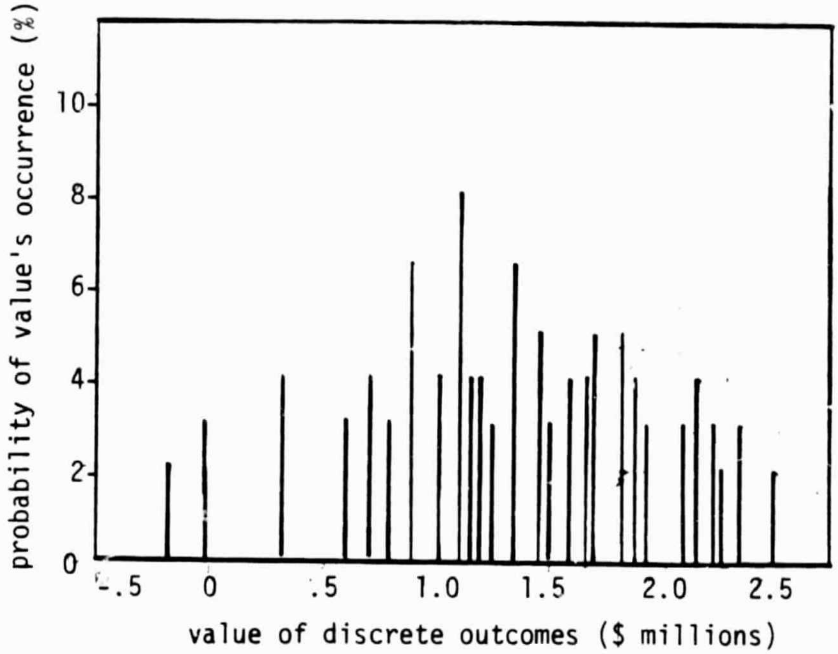
In our model of the five alternative decisions, the outcomes of only the "do not acquire" alternative are certain. Obviously in this decision the life cycle cost is "zero," the capabilities are "none" and the acquisition date is "never."

Figure 17: Probability Distribution of Life-Cycle Cost (example)



In comparison, acquiring software programs from COSMIC is oftentimes a decision with uncertain outcomes because many COSMIC programs are relatively unknown commodities. As discussed in the previous section, although the purchase price is much lower than most commercial software, the ensuing costs of integration and maintenance may range from very low costs to very high costs. Given the users' inability to effectively assess the program a priori (i.e., its architec-

Figure 18: Probability Distribution of Discrete Outcomes Value



ture, flexibility, efficiency, compatibility, etc.), these latter costs are highly uncertain. For these same reasons the system capabilities and the date of useability are also highly uncertain for most COSMIC programs. As a result the expected utility of a COSMIC program has a flatter probability distribution and its certain equivalent will be less than a similar program with more cetain outcomes.

In comparison, a turn-key system although having a large purchase price may have a much more certain life cycle cost. This is due to the fact that many turn-key suppliers bare most of the software's life cycle costs (i.e., specification, design, coding, testing, integration and maintenance) and the purchase price is nearly equal to the life cycle cost. The useability date is also usually highly certain since many suppliers will guarantee a specific startup date. The capabilities of a turn-key system are usually not this certain. But if a system is well defined, well documented and has been used by many people then the potential user has significant opportunities to gain more information about those capabilities to reduce that uncertainty at a relatively low cost.

The level of uncertainty associated with in-house software development can vary considerably. Relatively certain outcomes with narrow probability distributions (see Figure 13) are more likely in projects that have experienced programmers, simple program objectives or have had previous

projects that are similar in nature. If one or more of these facts is not present, the uncertainty of predicting the software's life cycle cost, capabilities or useability date can be high.

The uncertainty associated with the fifth acquisition alternative, purchasing the software from a software house, can also vary considerably. The user's ability to predict the life-cycle cost and capabilities will be a function of the level of vendor support and the amount of information available about the software from the vendor or other users. With widely used programs or reputable and supportive vendors these uncertainties will usually be relatively low although the price of the software will probably be higher.

In conclusion, due to the risk aversion of most corporate investors, uncertainty in a software program's life cycle cost, capabilities or useability date will result in a lower perceived value of the program by the prospective user. This result will cause prospective users to reduce the value that they assign to COSMIC programs due to the unknown nature of most COSMIC programs and the difficulty in acquiring more information on the programs from either the documentation or the small number of other users.

This paper does not say that steps should be taken to reduce this uncertainty but it should be considered as one possible method of increasing the use of COSMIC programs.

Appendix A

Size of COSMIC Computer Programs

	Program Size (source statements)					
	0-499	500-1499	1500-2999	3000-4999	5000-9999	>10000
Category						
total	62	72	61	22	36	33
aerodynamics	2	5	9	1	2	1
aircraft	2	2	3	0	1	2
auxilary systems	1	1	1	0	1	0
biotechnology	1	2	1	1	2	0
chemistry	0	2	0	1	3	0
computers	8	11	5	4	3	9
electronics	2	3	3	2	5	1
facilities, research and support	4	10	3	3	5	5
fluid mechanics	3	6	4	1	0	0
geophysics	2	3	4	0	0	0
instrumentation and photography	2	1	0	2	0	2
machine elements and processes	5	3	3	2	1	1
mathematics	20	9	8	3	2	1
structural mechanics	7	11	7	2	8	8
thermodynamics and combustion	4	2	8	2	1	3

NOTE: Obtained from "COSMIC - A Catalog of Selected Programs."

Appendix B

Average Size and Price of Selected COSMIC Programs

Category	# of programs	AS (avg.size)	AP (avg.price)	AP/AS
total				
aerodynamics	20	2866	502	0.18
aircraft	10	3561	558	0.16
auxilary systems	4	2109	478	0.23
biotechnology	7	3090	556	0.18
chemistry	6	3865	547	0.14
computers	41	5021	608	0.12
electronics	16	3465	706	0.20
facilities, research and support	30	4157	599	0.14
fluid mechanics	14	1409	422	0.30
geophysics	9	1276	371	0.37
instrumentation and photography	8	17715	761	0.04
machine elements and processes	15	2759	479	0.17
mathematics	43	1591	305	0.19
structural mechanics	43	5502	580	0.11
thermodynamics and combustion	20	3745	548	0.15

NOTE - Obtained from "COSMIC - A Catalog of Selected Programs"

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IMPROVING NASA'S TECHNOLOGY TRANSFER PROCESS THROUGH INCREASED SCREENING AND EVALUATION IN THE INFORMATION DISSEMINATION PROGRAM

Horstfried Läpple
October 1979

Abstract

This paper focuses on ways to improve NASA's technology transfer system. Secondary utilization of aerospace technology is made more difficult becaus t depends on a transfer process which crosses established organizational lines of authority and which is outside well understood patterns of technical applications. The analysis in this paper assumes that an improvement of the current status can be achieved if the technology transfer process is better understood. This understanding will only be gained if a detailed knowledge about factors generally influencing technology transfer is developed, particularly those factors affecting technology transfer from government R&D agencies to industry.

In the absence of a sound theory about technology transfer and because of the limited capability of government agencies to explore industry's needs, a team approach to screening and evaluation of NASA generated technologies is proposed. The proposal calls for NASA, and other private and public sector organizations which influence the transfer of NASA generated technology, jointly to participate in a screening and evaluation process to determine the commercial feasibility of a wide range of technical applications.

IMPROVING NASA'S TECHNOLOGY TRANSFER PROCESS THROUGH INCREASED SCREENING AND EVALUATION IN THE INFORMATION DISSEMINATION PROGRAM

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National Aeronautics and Space Administration

Contract NASW 3204

PROGRAM IN INFORMATION POLICY

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Abstract

This paper focuses on ways to improve NASA's technology transfer system. The analysis in this paper assumes that an improvement of the current status can be achieved if the technology transfer process is better understood. This understanding will only be gained if a detailed knowledge about factors generally influencing technology transfer is developed, and particularly those factors affecting technology transfer from government R&D agencies to industry. Secondary utilization of aerospace technology is made more difficult because it depends on a transfer process which crosses established organizational lines of authority and which is outside well understood patterns of technical applications.

In the absence of a sound theory about technology transfer and because of the limited capability of government agencies to explore industry's needs, a team approach to screening and evaluation of NASA generated technologies is proposed in the analysis which follows. The proposal calls for NASA, and other organizations of the private and public sectors which influence the transfer of NASA generated technology, to participate in a screening and evaluation process to determine the commercial feasibility of a wide range of technical applications.

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Introduction

In providing for the widest practicable and appropriate dissemination of information about its R&D activities, NASA faces a task of vast scope and substantial complexity.

In fulfilling its task NASA must solve two complex problems:

- The Information Problem

The secondary utilization of aerospace technology poses a question that is difficult to answer: "How can an unknown target group in industry be provided with a technology having unknown applications?" In order to respond to this challenge NASA must necessarily initiate "horizontal" technology transfer through a communication process which crosses institutional and organizational boundaries. This process is not well understood.

To transfer the right information to the right target group is a difficult task. But, this is only one part of the technology transfer process. Information dissemination is a necessary but not a sufficient condition for technology transfer (see also: Baer et al., 1976, p. 27).

- The Application Problem

There exists a spectrum of potential reasons why industry does not accept a known technology. Technological feasibility is no guarantee of commercial success. Furthermore, new technologies are very often not only market-creating but also market-destroying.

Studies indicate that NASA performs excellent work in disseminating information. That is not to say that there do not exist ways of improving the NASA information dissemination system. In addition, based on an interpretation of investigations performed by the Denver Research Institute, it appears that opportunities for substantial improvement exist in the application process.

Rather than attempting to improve the technology dissemination system through a new kind of technical report, it may be more beneficial to improve the information itself. More potential value could be added to the information system by detailing competitive technologies, by indicating neighboring technologies which already exist or are developing, by suggesting possibilities for useful applications, and by providing commercial feasibility information. Such activities impact on the application problem in a positive manner (see also: Chakrabarti, 1972, p. 7).

In order to effectively provide this "value added information," one must understand the supply characteristics of NASA technologies with regard to potential commercial applications and specific demand characteristics of potential users. In addition, one should be aware of "what is going on" in industry and between industry and government agencies.

How can such a task be accomplished? An important step is to enhance the <u>screening/evaluation process</u> of NASA generated technologies. That is to say, enhancing the ability

to anticipate the future value of a NASA technology and thereby choose an effective transfer medium. Since no comprehensive detailed knowledge about the many facets of technology transfer exists, two possibilities seem worth pursuing in the screening/evaluation process.

o <u>Statistical Analysis</u>

Based on existing historical data, one can try to determine the relevant characteristics of technologies which enhance their value for potential users.

Such statistical analysis could provide substantial insights. Industry, however, frequently reorganizes its structure and changes its needs, so statistical analysis is of limited value. But, statistical analysis might be used for preevaluation, thereby filtering out presumably valuable technologies to be evaluated by a team.

o <u>Team Approach</u>

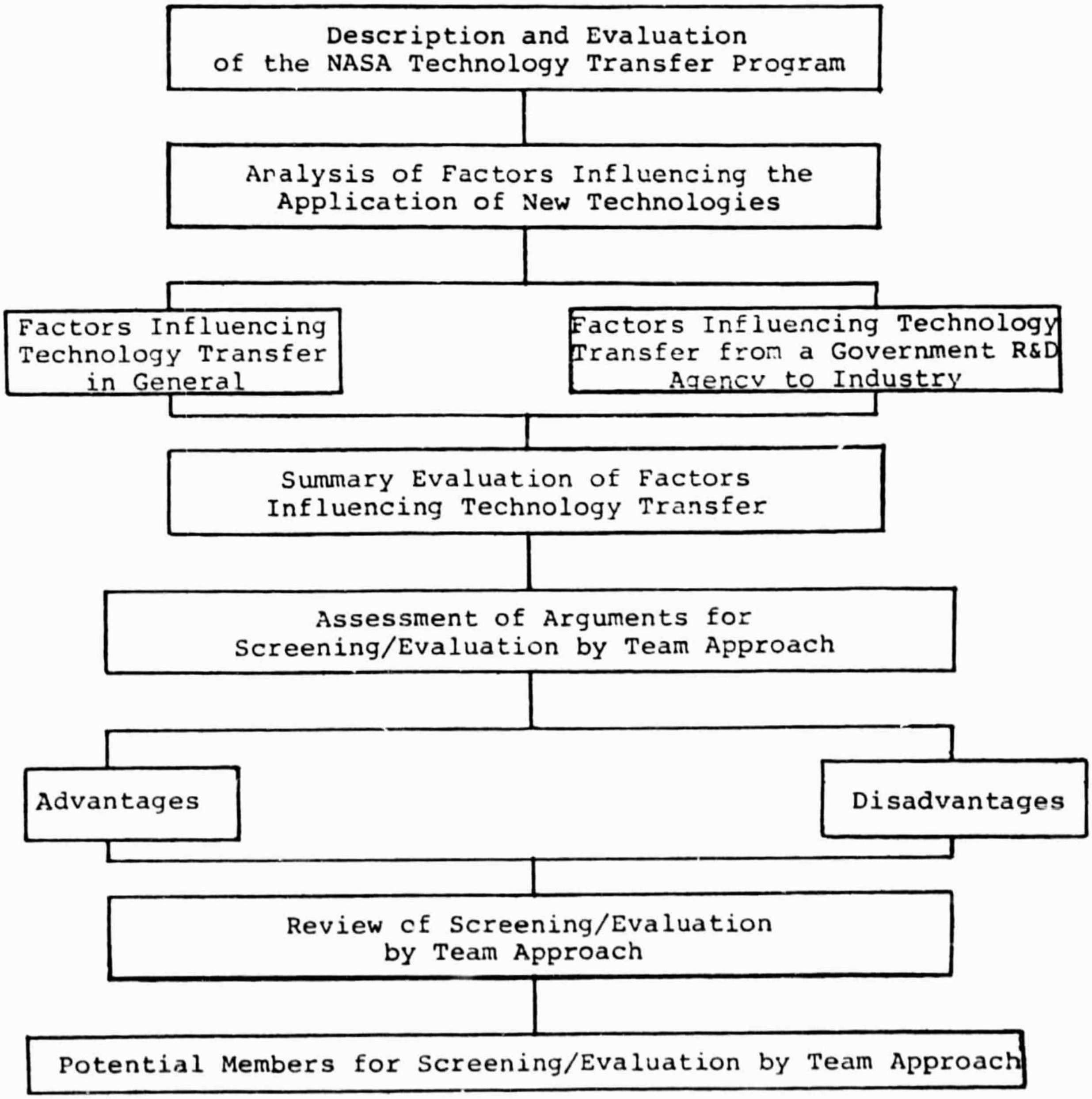
Evaluation using a team approach is suggested here using teams that include members of the user community, such as professional associations, and governmental agencies, which are concerned with regulation and commercial R&D. Such an approach would enhance the technology transfer process.

The purpose of this paper is to explore the potentials of a team approach to the screening/evaluation process. This approach creates two substantial benefits:

(i) Given a lack of knowledge about the complexities of technology transfer, this approach could become a powerful tool in overcoming those complexities.

(ii) Technology transfer is important for all members of a society and should therefore not be the sole concern of an R&D agency like NASA. A team approach would promote acceptance of the view that technology transfer is the common responsibility of all participants in the commercial utilization of advanced technologies.

To outline the characteristics of a team approach to screening/evaluation, this paper is organized as follows:



In the first section below, the NASA information system is described and evaluated. This evaluation suggests that NASA improve the information itself rather than modifying the information dissemination system.

An assessment of factors which are likely to impact on technology transfer is made in the second section. At the end of this section, improvements achievable using a team approach are discussed.

The third section assesses arguments for a team approach to screening/evaluation.

Potential members of a screening/evaluation team are noted and their capabilities explored in the fourth section.

1. <u>Description and evaluation of the NASA Technology Transfer Program</u>

The NASA Technology Transfer (TT) program consists primarily of Information Dissemination, Application Teams, Information Dissemination Centers, and Applications Engineering. For the purpose of this paper, this transfer system is viewed as three phases:

<u>INFORMATION PHASE</u>

- library service
- delivery service (technical reporting)

<u>MARKETING PHASE</u>

- identification of potential users' needs
- identification of technologies matching users' needs

APPLICATION PHASE

- o demonstration projects
- o reengineering projects
- o production of marketable products

The development of the process can be thought of as an evolution. In its information phase, information is provided for the users. In order for technology transfer to happen, the user must play an active role. NASA's role is more passive, once information has been made available. The library service, for example, consists of a set of interrelated services. In the literature search service ("remote") the user is active; he defines key words which are used for information retrievals performed by Industrial Applications Center's (IAC) personnel. The next extension is an interactive retrieval service (on-site); the user sits beside the "Information Specialist," who now plays an active part due to his knowledge about the NASA data base. He is able to identify keywords the user might never think of. In a current awareness search service (periodical reports which supply the user with up-to-date information in his field of interest, generally delivered on a monthly basis), the user defers to the search service totally. NASA's role is more active in cases where the user requests interpretative services and NASA participates in the exploration of the retrieved information.

Staffed with highly qualified scientists and engineers, Industrial Applications Centers provide not only information but potential applications of information. An IAC's staff

personnel may initiate contact between a requester and companies, universities, etc., already working in a certain field.

In the marketing phase, performed by State Application Centers and Technology Application Teams, NASA takes a more active role: exploration of a user's needs, search for a technology which will match those needs and then implementation and commercialization of the technology (see Anyos et al., 1978. p. iii). In the application phase, NASA reengineers technologies in order to bring them closer to commercial feasibility.

Studies investigating the benefit-to-cost ratios concerning the main elements of the NASA Technology Transfer program show a positive relationship. The aggregate benefit-to-cost ratio was estimated to be 6 : 1. The single elements of the program are characterized by ratios lying in a spectrum 3 : 1 to 26 : 1 (Johnson et al., 1977b, p. v, vi). For each dollar NASA invests in its TT Program, benefits equivalent to six dollars are produced.

When interpreting these numbers, one must take several factors into account. First, such benefit-to-cost ratios cannot be directly compared with those of other NASA projects. Of course, the ratios calculated for the NASA TT program do not reflect the investment in developing the technology. Second, each NASA contractor must write a contractor report, which can be thought of as an initial step toward producing an information product, the costs of which are not covered by the TT program.

In assessing possibilities for further improvements of the TT program, an analysis of the NASA Tech Brief Program, under-

taken by the Denver Research Institute, is most valuable (Johnson et al., 1977a, p. 36). They classified TT applications in four modes:

mode 0 no application at all

mode 1 used for information only

mode 2 used to improve already existing production technologies, products and services

mode 3 used to develop new production technologies, products and services

The probability for any of the individual modes occurring were calculated as follows:

mode	probability
0	34%
1	54%
2	11%
3	1%

The 54% for mode 1 indicates that NASA is providing an excellent information service. There is no other information service available which covers the aerospace area and related fields in such a comprehensive way. This is true partly because the NASA data base includes information produced by other organizations. For example, due to a special information exchange agreement between the NASA Scientific and Technical Information Office (STIO) and the European Space Agency (ESA), a user can obtain the latest international developments in this field.

The results of the DRI study show a very different picture concerning the development of new products from NASA technical

information: "Successful efforts to develop new products from TSP's have occurred but they are exceptions. More typically, such attempts lead to a new financial loss for the TSP requester. Even for successful Mode 3 application (development of new technologies, products, services), the TSP information is usually a minor technical input (about 5 percent) to the new economic activity" (Johnson et al., 1977a, p. 48).

At the present time, it seems that the most positive outcome of NASA's TT program is that the information about its technologies is available promptly and comprehensively.

The calculated net benefit for the Industrial Application Centers is moderate compared to those of the technical reporting program. One might expect the contrary, due to the comprehensive and thorough services provided by IACs. Moreover, it is important to emphasize that while technical reports are free, users are charged for the services of the IACs. The benefit-to-cost ratios currently available may not describe the true picture. Out of a vast set of new technologies, most will have little or no impact on new products and services. There is a small subset of technologies which are, unexpectedly, so successful that they pay for the whole R&D program of an organization.

To enhance the effectiveness of NASA's TT program, it would be useful to know about the underlying factors which influence technology transfer. For example, it is not particularly useful to calculate time-lags between the technological feasibility and the first commercial application of a technology;

indeed, those calculations show substantial variations (see: Rosenberg, 1976a, pp. 72-74). There are many different factors at work and without a detailed understanding of those factors it is hard to initiate efforts to make technology transfer more effective.

NASA technology has the potential to improve existing technologies and to develop new production technologies, products and services. However, an improvement of the technology information dissemination system by itself is not likely to lead to a substantial change. Producing and reproducing information about a technology where there are barriers in the application of this technology is not likely to lead to better results. In one case hundreds of TSPs were requested regarding a new gas turbine seal, but there were no applications because no firm was willing to take the necessary substantial commercial risk. If a procedure existed, e.g. a team approach to screening/evaluation by which NASA anticipated such a problem, NASA could offer more help. For example, where potential users of a new technology such as governmental organizations are identified, NASA might develop a prototype if the technical risks were so high as to inhibit further development.

The key for solving the applications problem is a mechanism which enables NASA to explore the potential commercial environment for a certain technology which is announced through the TT program. This is the underlying basis for the suggestion of technology screening/evaluation using a team approach.

2. Analysis of factors influencing the application of a new technology

Technology transfer is a complex process which is not well understood (Hoelscher, Hummon, 1977, p. 76), especially horizontal technology transfer or secondary utilization. There may be hundreds of potential secondary applications of aerospace technology, but it is extremely difficult to identify them. Indeed, it might be difficult to think of any useful applications of a new technology at all. Thomas Edison is reported to have thought that a phonograph would be used to record the wishes of dying men (Rosenberg, 1976a, p. 197).

In the secondary utilization of aerospace technology, it is often remarkable how remote the secondary utilization is from the original space application. A joint NASA/military project on helicopter rotors produced a vibration dampening technology, now used in building guitars (Haggerty, 1978, p. 34).

In anticipating secondary utilization one faces an "open-ended" problem. There will never be a method for identifying all the possible or useful non-aerospace applications of a NASA technology. "It is important that one never knows in advance if spinoffs will occur, or what their benefits may (or may not) be. Because of this uncertainty, spinoffs are nothing to bank on." (Thurow, 1978, p. 69.) It might be worthwhile to initiate a potential applications "creativity-session" for selected technologies. Such value added to a purely technical description of a new technology might enable a reader of a TECH BRIEF to envision many possible applications and ultimately to develop a useful application.

Before one explores the potential value of a technology, an idea for the application of that technology is necessary. One can then begin to assess the impacts of factors influencing the technology transfer process. A knowledge of such factors and their impacts on technology transfer is important in estimating the probability of an industrial application of a technology. In the following paragraphs some of those factors are discussed.

2.1 Factors which influence technology transfer.

The following section describes some factors which generally influence technology transfer as well as specific factors which influence transfer from government R&D agencies to industry.

o All technologies have certain characteristics making them advantageous for some applications and useless for others. The application of numerical control in the machine tool industry is not economical for long production runs. Other factors like preparatory and maintenance work have to be taken into account, especially if a skilled work force is scarce. (see also: Ray, 1969, p. 58). One must also check the impacts of a new technology on the organization of the whole production system. This is extremely important in industries like the chemical industry which is characterized by close and interdependent relations between materials, energy and information flows. Often, a new technology - even if only a small piece - can only be used advantageously if the whole production system is reorganized. If the investment expenditures for the re-

organization are greater than the anticipated cost reductions caused by the use of the new technology, the latter will be ignored.

It is extremely difficult - if not impossible - to detail the general characteristics of technologies, due to the fact that production systems differ from industry to industry and even within a certain industry. Quite a few mathematical models have been developed to describe the behavior of an industry, e.g. the oil industry. But the value of those models for the explanation of industry's behavior concerning the adoption of new technologies is only moderate (Läpple, 1978, p. 284). Assume that there are two different technologies for the production of a certain product, one of which is relatively more energy consuming than the other one. Without specific knowledge about the production system of a firm, there is no way to anticipate which of the two technologies will be applied. For example, the more-energy-consuming technology might produce valuable by-products which far outweigh the cost advantages achieved by using the less-energy-consuming technology.

In the screening and evaluation of NASA generated technology it is valuable to know about the factors described above. It is extremely difficult to achieve such detailed knowledge on an industry-by-industry basis. In this context, technology screening/evaluation using a team approach would be a valuable asset in gaining knowledge about those characteristics of specific technologies which are relevant to the technology transfer process.

o The degrees of technical and business alignment between industries is an important parameter in the technology transfer process. It is reasonable to assume that the less alignment between industries exists the less likelihood there is of successful technology transfer between industries, and the more important technology transfer programs become in promoting the transfer process (see also: Kottenstette, Rusnak, 1973, p. 106). Therefore, knowledge of the degree of technical and business alignment between industries is essential to planning technology transfer programs.

o Due to the fact that each field in science and technology has developed its own information channels and has created individual problem-solving methodologies, there exist <u>interdisciplinary barriers</u>. Normally, people not trained in a special field are unable to communicate with people who are. The party unable to understand a certain professional language may be unwilling or unable to learn this language. Consequently, there exist barriers between fields in science and technology. The difficulty of overcoming interdisciplinary barriers can be assessed by analyzing an interdisciplinary field. In the American Journal of Operations Research about 10% of published articles are of interest to a special target group but actually only 2% to 4% reach this target group (see: Pierskalla, 1979, p. 8) due to "language" problems.

Of course, to overcome those problems specialized journals can be issued. The Operations Society of America is doing this,

for example, by issuing the Journal of Transportation Science. Within this Society there are plans to pursue this approach in other areas by issuing journals on such topics as public systems and marketing (Little, 1979, p. 4). NASA uses a similar technique when it issues bibliographies in areas such as Aerospace Medicine, Biology, Earth Resources, and Energy.

This approach, issuing journals in selected areas, has limited advantages. It is impossible to issue journals in all areas of potential interest and, furthermore, people are often reluctant to use new journals.

A different approach could be adopted. Rather than issue journals, it is possible to develop close relationships with societies already covering a certain field and publish articles in established journals. A team approach to technology screening/evaluation is based upon strong relationships with organizations which cover different areas in science and technology. Doors to these areas would then be opened.

o Estimation of the relative efficiency of a new technology in comparison to already existing ones is an important factor to take into account. Often a new technology offers few or no advantages in terms of technical and cost aspects when compared to those already in use (see also: Cooper, et al., 1973, p. 56). Sometimes engineers need a substantial amount of time to find out efficient ways to operate a new process. This is particularly true for chemical process industries due to the absence of a comprehensive understanding of the production process in many cases.

Often, technologies already in use experience substantial improvements when a new technology is expected to enter the market. For example, the slow diffusion of the steam engine in the United States was caused by improvements in water-wheel technology (Rosenberg, 1972/73, p. 24). Estimation of "switch-over-points," and the efficiency curves of old and new technologies, is a difficult task. In most commercial enterprises, it is rare that a new technology can be used with great success immediately. This situation delays the use of a new technology. The knowledge of this delay is of major interest due to the fact that the new technology might itself become obsolete prior to implementation.

o In some cases one would fail in judging the value of a new technology without analyzing its <u>"neighboring" technologies</u>. To some extent, each technology is dependent on other technologies. For some new technologies, essential neighboring technologies might not be available. Consequently, one must overcome numerous bottlenecks (Rosenberg, 1976, p. 125). Often, efficient technologies cannot be used because "parallel necessary technology did not arise elsewhere." (Locke, 1978, p. 25.) It takes time to make neighboring technologies available due to the fact that 6 to 10 years are often required to develop a process from pilot stage to industrial scale. If such bottlenecks are anticipated, one can initiate appropriate steps to make the new technology more readily available for applications in the commercial area.

o In almost all cases production technology is <u>capital-intensive</u>. If an industry is dominated by a small number of

big firms, they might agree to ignore a new technology in case it would cause a major impact on existing production technology. A study of Du Port rayon plants points out that delays in applying new technology stemmed from the fact that the new technology required new investments (Hollander, 1965, p. 199). If capital goods already in use are relatively new and characterized by long life cycles, the long-run cost advantages of a new technology might be outweighed by short-term financial returns (Ray, 1969, p. 45).

The behavior of the American steel industry in the fifties can be cited in this context. Although the oxygen furnace process had proven superior to the open-hearth process in Europe (Gruber, 1969, p. 43), the U.S. Steel industry switched over to the oxygen furnace process relatively late. The capital intensiveness of the production technology seemed to be a major reason for this delay (see also: Gruber, 1969, p. 49, 50). A spokesman for the U.S. Steel Corporation said that: "Nobody who has efficient open-hearth furnaces is going to throw them out to buy oxygen furnaces. We waited until we needed to replace old capacity." (in: Ray, 1969, p. 45.)

On the other hand, if a new technology is able to overcome bottlenecks in an existing production system and thereby offer incremental change compatible to the existing technology, it is likely that such a technology would be used immediately. An investigation performed by Wright points out that industry's interest regarding those NASA generated technologies offering improvement on existing technologies was nearly eight times

greater than industry's interest in technologies not compatible to those already in use (cited in: Chakrabarti, 1972, p. 7).

o An important factor in technology transfer is the comparative advantage a firm gains in using a new technology. In judging contractual arrangements one should take into account that "the smaller the variation in comparative advantages among prospective innovators of the same idea the less will the exclusive right to invent be worth, even if the returns were fully capturable" (Cheung et al., 1976, p. 19).

Regulations requiring mandatory use "of the best available technology" are also an important consideration. In a case where a new technology will turn out to be a "best available technology," an innovator will not enjoy a comparative advantage due to the fact that other firms are forced by law to follow. Furthermore, other firms then have an incentive to hinder potential innovators (Hill, 1975, p. 139).

Another case to consider is a major change of the production technology in an entire industry branch. At present, some 80 percent of products in the chemical industry depend on oil. To switch to coal, major changes must take place. If one firm goes ahead it will face tremendous risk. Other firms, choosing the "second is fastest" strategy, would gain technical knowledge by monitoring the research work of the innovator (Thurow, 1978, p. 70). They will follow only if it is economical to do so. The first firm may not gain substantial comparative advantages. If one is able to anticipate such factors, one

can arrange appropriate steps; for example, joint projects between NASA and all major firms within an industry branch, or an industry association.

o New technologies are both <u>market-creating and market-destroying</u>. Market-destroying effects will be greater the more existing technology is integrated into the production system. It is important to realize that it is insufficient to assess those effects only at the firm level. For example, replacement of pesticides might impact the cosmetics industry because both industries use common raw materials. Also, restrictive sulphur emission standards caused oil companies to develop technologies to produce sulphur out of their residuals. Consequently, medium-sized firms which produced sulphur out of elementary sulphur were nearly eliminated. Finally, West Germany experienced labor strikes due to the introduction of text processing technologies. Printers were frightened of losing their jobs overnight.

Attempts of oil companies to achieve control over competitive uranium and coal technologies "may be seen as attempts to assure long-term market control by minimizing the potential threats arising from technological breakthroughs in the provision of substitute products." (Rosenberg, 1976b, p. 533). A recent example is the behavior of the electric utilities towards solar power due to the fact that such a decentralized energy source does not fit the structure of existing centralized power line networks (Commoner, 1979, pp. 69-71).

Those examples clearly show that the market-destroying effects of a technology may lead to the non-application of a new technology or at least a delay in the diffusion process. In assessing the value of a new technology, it is important to keep in mind that it must "become an element of the socio-technological fabric" (Hoelscher, Hummon, 1977, p. 78) and for a firm "of the various kinds of environmental change, few are more pervasive or important than technological change" (Cooper et al., 1973, p. 54).

o <u>Regulation is an important factor to take into account</u>. A major influence is expected from regulations implemented in the form of so-called design characteristics. A firm may feel it is inconvenient to try to change governmental rules for the benefit of a minor improvement and thereby will not use a technology which only leads to moderate benefits.

However, careful analysis can help anticipate industry's behavior. Regulation causes technology arrestment as well as technological advance. One of the industries most affected by environmental regulation is the chemical and allied products industry. This industry claims that this kind of regulation leads to a decline in capital productivity due to the fact that investments for reduction of emissions decrease the amount of capital used for the production line. This argument holds true, but only assuming that no technological advances are made. Indeed, under this assumption a substantial quantity of capital has to be invested for the treatment of residuals without any benefit for the production processes. An investi-

gation performed in West Germany (Meissner, Hoedl, 1978) showed that industry has strong incentives to change this "unpleasant" situation, and one efficient means to do so is to change the production technology. In this case, regulation caused a need for new technologies. In general, only detailed analyses will lead to a well balanced judgement about the impacts of regulation on technology transfer.

o Another extremely important factor is the relation between the development of a technological innovation and the development of the diffusion process. It seems reasonable to assume that industry will slow down the adoption of new technologies if the speed of innovations is high. This assumption is based on the fact that firms face the danger of investing in "soon-to-be-obsolete technology." (Rosenberg, 1976b, p. 534.) While such a pattern might be characteristic of a lot of cases, it does not hold for all. In the computer industry, important innovations are characterized by a diffusion time of 3 to 5 years; innovations of less importance are delivered to the market within 1 year. Firms must be heavily active in R&D in order to achieve a competitive position in the market (Dunn, 1979, pp. 3-4).

Competition is a strong force in promoting the application of new technologies (Gruber, 1969, p. 40). In assessing rates of innovation and diffusion, competition should be taken into account.

o Dependent on its stage of development, a firm shows different responsiveness to different kinds of innovations.

Utterback offers the following model for explaining this phenomena (1976, p. 36):

During the first stage, development is based on product change primarily. Consequently, product innovations have priority over process innovations. Based upon experiences, e.g. in the semi-conductor industry, firms concentrating on process innovations in this early stage face the danger of improving the production-technology of a product which soon becomes obsolete.

The second stage finds established firms in an industry looking for process innovations. These small changes, compatible with the existing production system, reduce costs of existing products.

In the last stage, established firms have an incentive to delay major technical changes because of the inflexibility of capital-intensive production systems. It might be possible to obtain such knowledge by monitoring the development of an industry.

Those factors influencing technological change mentioned above provide a few hints; the list is neither complete nor exhaustive. Yet, the rather brief discussion showed the importance of those factors and the difficulty of exploring their impact on technology transfer. To make technology transfer more effective, however, knowledge about such factors seems to be essential (see also McClain, 1976, p. 116). Therefore, I will now explore the impacts of such factors on the secondary utilization of aerospace technology. Anticipation

of those impacts is a necessary condition for choosing appropriate steps in "putting technology to work."

2.2 Factors influencing technology transfer from a government R&D agency to industry.

The factors discussed above are generally important. Those factors analyzed in what follows are of particular interest if the transfer process takes place between a governmental agency to industry. The analysis will focus on such factors important to NASA's TU program.

o For the successful introduction of a new technology the relation between innovation and innovator is most important. Therefore, many firms have adopted a procedure whereby the innovator becomes the product manager for his own product. This reflects the fact that an innovation needs a key individual who pushes it from innovation to commercialization. An empirical investigation of NASA generated technology further points out that the involvement of the innovator in the usage of the innovation is important for success (Chakrabarti, 1972, p. 28). Furthermore, an investigation of federally funded demonstration projects showed that in cases where the project initiative originates from nonfederal sources, the diffusion process is better than projects initiated by a federal agency (Baer et al., 1976, p. 48).

o Psychological barriers to the use of government information and technology and, to some extent, the restricted availability of government information must be taken into account. Up until now industry has hesitated to use govern-

mental information and technology. There is - justified or not - a concern that government might try to influence its activities or at least monitor requests. This problem is reinforced because NASA's data base is not as easily available as other federal data bases. But it seems likely that such barriers can be overcome. A DRI study points out that users, if they have once used NASA services successfully, are likely to do so in the future. A review of the number of users of NASA's data base appears to show an educational process taking place.

Concerning the restricted availability of NASA literature, it is worthwhile to think about improvements. It normally takes a user 1 to 2 weeks to receive the printouts of a literature search service. The information is rarely published in widely available professional journals. Instead it is published in NASA journals which are in most cases only available in NASA Centers and through the National Technical Information Service. Consequently, it takes at least one to two months before a user receives the information.

Further, it might be valuable to improve the "On-Site" literature search service. An intelligent user should be able to screen the information while sitting at the terminal; under current conditions, it is too time consuming to do so. To improve the procedure, "touch-panel" terminals could be installed at the Industrial Application Centers. Those industries remote from the aerospace industry are more likely to be attracted if access to NASA information is made easier.

o The value of NASA generated technology is of critical importance. NASA's philosophy - especially that of the IAC's - that it is wasteful "to reinvent the wheel" - is often not accepted by industry regarding NASA generated technology (see e.g. Olken, 1972, p. 617). It has been argued that NASA technology is the result of reorganizing what was already at hand, that is to say NASA technology lacks novelty. Miniaturization was a new concept in the sixties but is now a well-known design technique. In general, government information is characterized by the label: too much, low value.

To counter such labels, many factors must be explored. At first, it is quite natural that "massive-mobilization R&D projects" (Thurow, 1978, p. 30) like Apollo and the Space-Shuttle can be successfully performed only if the basic knowledge about the technologies employed already exists.

This means that NASA technologies are in a much more advanced application stage. This should not be confused with the value of such technologies. This situation reinforces the need to develop a technological classification scheme which separates basic knowledge, engineering-application knowledge, etc. This classification scheme would enable NASA "to shoot" at appropriate target groups with efficient transfer mechanisms. It is extremely important that a rapid transfer of engineering-applications takes place due to the fact that such knowledge rapidly becomes obsolete. In such cases, it is not a question of technological availability but of whether the technology is known to all potential users. This leads to a second

important fact. A certain technology might be well known; a special technique might be general knowledge in one industry, but there is no way to know if this knowledge is available to other industries as well. Vertical technology transfer, a process within one industry, works quite well. In contrast, there are no established mechanisms for horizontal technology transfer, a process which takes place across organizational and industry borders. Kottenstette and Rusnak describe these three caveats (1973, p. 106):

(i) "Firms have varying degrees of technological alignment with aerospace and their relative alignment is of primary importance in effecting secondary utilization."

(ii) "Increased distance from the aerospace sector (less alignment with aerospace) decreases the likelihood of new technology adoption through diffusion."

(iii) "Increased distance from the aerospace sector implies that a planned effort is required to provide access to the aerospace technology."

Communication between firms is important to the transfer of technologies (see Utterback, 1971, p. 82, 83). To estimate the value of aerospace technology for other industries, one might use an "alignment structure" plan: (described below) and organize transfer efforts around such a plan.

Such an alignment structure plan can be illustrated in the form of a graph or a matrix which describes relations between firms. Such an approach was used by Czepiel (1975) to explore the diffusion of the continuous casting process in the steel industry. The arcs in the graph, or the elements in the matrix, represent two kinds of flows--material and information. It is valuable to consider firms and other organizations

of the private and governmental sector which influence the technology transfer process. That is to say, the alignment structure plan should represent the entire "technology delivery system." The main components of a technology delivery system are: source of R&D funding, R&D performers, material supplier, manufacturer of the capital goods, producers of the product, distributors, ultimate users (see also: Yin, 1978, p. 13).

In exploring the value of NASA technology for industry one should keep in mind that this technology has been developed for NASA mission-oriented R&D projects. This is to say that the technology is not developed in a commercial environment. There is a trend, as in the military field, to produce such technologies as soon it is technically feasible. Technical feasibility is no guarantee of commercial success. Of course, there are a lot of fine, commercially successful technologies, like integrated circuits, jet airplanes, etc. But there are other cases, like the nuclear-driven ship.

To sum up, estimating the value of NASA technology is not easy; it requires knowledge or at least three primary components. First, the stage of technological development, from vague ideas to prototypes. Second, the relation of other industries to the industry generating the technology. Third, the commercial "shape" of the technology.

o Aside from the specific value of NASA generated technology the value of externally generated information about technologies in general has to be taken into account. Many firms believe that externally generated knowledge, when compared to its own R&D, is not as unique as is often claimed (VDI, 1979, p. 18). It is important to realize that in any case the firm must check the information. As a result, the value of a Tech Brief is known to a firm only after a check of its content; that is to say, after the firm has invested time and money (Johnson et al., 1977a, p. 11).

Refusing to adopt externally generated technology seems to be typical of U.S. firms, at least when compared to firms in Japan and West Germany. There is some feeling that "an overall increased sensitivity to and utilization of outside technology must be developed..." (Gee, 1978, p. 212). In general, such behavior is caused by factors described in the previous section. For example, in chemical industries there are huge and complex integrated production systems. The change of one element might impact on many other elements. Therefore, incremental improvement is typical; major changes of the production technology tend to be delayed. Major new technologies are often created outside the established firms but are, in many cases, neglected due to the large capital investment in existing technology (see also: Abernathy, Utterback, 1978, p. 41). Firms in the U.S. have also been reluctant to undertake cooperative programs. While these

programs are quite common in Europe only a few exist in the United States (U.S. General Accounting Office, 1978, p. 58). In the future this problem might be partly eliminated. The experience of MIT after working with industry under a NSF grant for several years indicates that once firms "enter into cooperative research, they discover that it does not threaten their competitive position" (U.S. General Accounting Office, 1978, p. 60).

The factors discussed above are only a few out of a large set. It is not intended to provide a complete list. An attempt was made to demonstrate that government R&D agencies face specific difficulties in promoting technology transfer, difficulties which add up to those confronting technology transfer in general.

2.3 Summary evaluation of factors influencing technology transfer.

After having discussed factors influencing technology transfer in general and in particular those factors influencing transfer from a government R&D agency to industry, a short summary is provided in the following:

Factors Influencing Technology Transfer in General

- o relative efficiency of new technologies compared to those already in use
- o availability of neighboring technologies
- o capital intensiveness of new technologies
- o value of externally generated information about technologies

Factors Influencing Technology Transfer from Government R&D Agencies to Industry

- o psychological barriers to use of government generated information and technology
- o value of NASA generated technology to industry
- o relation between innovation and innovator

Factors Influencing Technology Transfer in General (Cont'd)

- o comparative advantage achieved by the entrepreneur
- o market-creating and market-destroying characteristics of new technologies
- o interdisciplinary barriers
- o technical and business alignment between industries
- o major changes of the production technology in a whole industry branch
- o regulation

All of these factors may influence technology transfer in a negative manner; at least to delay adoption of a new technology. Therefore, to solve the application problem described in the introduction of this paper, it would be extremely useful to explore NASA technologies with regards to such factors. If the results of such investigations are added to information about a certain technology, benefits might be achieved. In case a new technology is announced by NASA, it might be useful to know to what degree this technology fits current industrial patterns. One can identify material suppliers, producers of equipment, etc. which are able to supply the technology. Such knowledge--gained by exploring factors influencing the transfer process--provides a basis from which to choose the right steps to put a technology to work. To some extent, such value-added functions are performed by

staff members of the Industrial Application Centers. Users of the IACs' services can be directed to other organizations working in a certan field. Furthermore, staff members of the IACs provide valuable information concerning market analyses. In order to realize a real breakthrough in technology transfer such services should be provided on a comprehensive basis.

Under current conditions the screening and evaluation process concerning the Tech Brief is performed mainly by the Technology Utilization Officers at the single NASA Research Centers in conjunction with the Illinois Institute for Technology Research Institute. The screening/evaluation process employs the following criteria:

- o marketing potential
- o novelty
- o technology
- o nonaerospace potential

If an in-depth analysis of the factors influencing technology transfer is performed, it is likely that procedures can be developed providing for substantial improvement in the screening and evaluation process. Concerning the screening and evaluation criteria of "marketing potential," the following procedure might be developed.

o <u>Marketing Potential</u>

Market Destroying Effects	o Identification of already existing technologies to be replaced in part or in total.
	o Anticipation of improvements of technologies to be replaced.
	o relative efficiency of existing and new technologies over time.

Market Destroying Effects (Cont'd)	o	Estimation of future rate of innovations concerning the new technology.
	o	Necessary reorganizations of existing production systems to integrate the new technology.

As mentioned before, new technologies are both market creating and market destroying. The market-destroying effect is important in the development of market-potential estimates. First, existing technologies which are likely to be replaced in whole or in part should be identified. In many cases those technologies already in use undergo substantial improvements if a new technology is expected. Therefore, such improvements should be anticipated. Such investigations establish a comparison of the relative efficiency of the technologies already in use, and the new technology to be introduced. This relative efficiency is one of the important decision criteria in determining if a new technology will be used. Furthermore, the potential for further technological innovations should be checked due to the fact that industry is reluctant to invest in soon-to-be obsolete technology. Also, necessary reorganizations of existing production systems in order to integrate the new technology should be considered.

The information dissemination process might be made more effective if the dissemination strategy were based upon a structure alignment plan which indicated to what extent organizations influencing technology transfer are linked together.

After discussing a screening and evaluation procedure which takes into account factors influencing technology transfer,

I will undertake an analysis of policy options to enhance technology transfer.

Technology transfer has often been described as "technology push" or "demand pull." Most empirical studies point out the superiority of demand pull. However, R&D agencies, like NASA, are likely to push technologies. New technologies need pushing in order to overcome barriers, especially in early transfer phases. Often R&D agencies fail to push a new technology when industry has a need for it. In exploring factors influencing technology transfer, as mentioned before, NASA should incorporate industry's needs in its information dissemination policies. The outcome of this approach would be a mixed policy, linking technology push and demand pull. This approach is in line with recent findings. An investigation performed by Mowery and Rosenberg (1979) provides an in-depth analysis of eight of the best known empirical studies on technological innovation which all support the demand pull policy. The authors of the investigation, in analyzing these empirical studies, claim that "the role of demand has been overextended and misrepresented, with serious consequences for our understanding of the innovative process and of appropriate government policy alternatives to foster innovation" (Mowery, Rosenberg, 1979, p. 3). In the conclusion of their study, the authors point out:

> The existence of an adequate demand for the eventual product is, of course, an essential--a necessary--condition. But, we suggest, the demand pull approach simply ignores, or denies, the operation of a complex and diverse set of supply side mechanisms

> which are continually altering the structure of production costs (as well as introducing entirely new products) and which are therefore fundamental to the explanation of the timing of the innovation process.
>
> At a more general level, the conceptual underpinnings of the "demand-pull" case are perhaps even more fundamentally suspect. Rather than viewing either the existence of a market demand or the existence of a technological opportunity as each representing a sufficient condition for innovation to occur, one should consider them each as necessary, but not sufficient for innovation to result; both must exist simultaneously. (Mowery, Rosenberg, 1979, p. 57.)

In sum, successful technology transfer must be based upon both technology-push and demand-pull (see also: Hoelscher, Hummon, 1977, p. 82; Gilpin, 1976, p. 170).

As such, NASA might consider the "timing of publishing." To push a new technology at a time when industry has an urgent need is likely to produce more success than announcing a new technology at any time. An empirical study of NASA generated technologies published in a TECH BRIEF points out, that "the degree of urgency of the problem to which the technology was related seemed to be an important factor..." (Chakrabarti, 1972, p. 162). At a time of low gasoline prices, where no substantial change is expected, it is not appropriate to push electrical automobile engines. But when gasoline prices are increasing, industry might well be responsive.

Of course, one might argue that it is not NASA's task to explore industry's needs and that NASA should announce new technologies when they are produced, making sure that the information can be retrieved by industry at any time. Nevertheless,

hitting the right target group at the right time with the right information might lead to more effective technology transfer and "timing of publishing" might be a method worth considering.

In general, incorporation of users' needs in policies for technology transfer is essential. This kind of approach is now commonly employed by R&D funding organizations (Yin, 1978, p. 12, 13); NASA's TT program is an example. It is not a question of whether or not a government R&D agency (like NASA) should employ such an approach, but rather it is a question of how to implement it.

3. Assessments of Arguments for a Team Approach to Screening/Evaluation

3.1 Advantages of a team approach to screening/evaluation

The objective of this discussion is to describe possible positive effects on the technology transfer process of technology screening/evaluation using a team approach.

o One main advantage of screening and evaluation by a team of industry/government individuals is that this approach may come to grips with everchanging factors which influence technology transfer. The discussion in previous sections has outlined the difficulty of determining which factors influence (positively or negatively) technology transfer. Furthermore, underlying cause-effect relations are not constant but change

over time and are difficult to anticipate. The author of this paper assumes that a complete understanding of the factors influencing technology transfer will never exist. This is probably the main reason that the vast number of empirical studies on technology transfer have provided only limited help to policy makers formulating policies to enhance technology transfer.

However, an effective transfer system should allow a rapid check of which factors influencing technology transfer are relevant--even in a time of rapidly changing cause-effect relations--and thereby make possible the choice of an effective transfer mechanism. A team approach might fulfill this task because organizations influencing the technology transfer process would participate in the screening and evaluation process. Thus, the opportunity exists for all relevant information to be promptly available. For NASA this approach would provide a valuable opportunity to ask "what-if" questions of extremely knowledgeable and technically capable partners.

o Assuming that other organizations joined the screening/evaluation process, it is likely that a balanced assessment of the potential value of NASA generated technology would be possible. Furthermore, because most NASA technology is produced under relaxed commercial restrictions, and because technological feasibility alone is no guarantee that a certain technology will be commericializable, industry hesitates "to pick up" such technologies.

Also, shortcomings in technology transfer occur because potential users lack relevant information concerning commercial feasibility (Udell, Johnson, 1978, p. 177). With the help of other organizations, NASA might be able to provide such valuable additional information and thereby increase the probability of successful transfers.

o An important "by-product" of a team approach to screening/evaluation would be access to other transfer mediums. In case a professional society participates, one might think of announcing NASA generated technology in a variety of ways:

- in a professional society journal
    - under NASA's name
    - anonymously
        - as a standard publication
        - in an "innovation column"
- in a journal issued by both NASA and the professional society, etc.

There are many possibilities. The outcome of such options would be (amongst others):

- a higher reputation for NASA technology because the reader would consider NASA information as competitive with other information announced by a professional society
- better access to NASA information

Concerning access to NASA information, it was mentioned previously that under current conditions NASA information is not that easily available to a potential user. Most information is only published in NASA journals, such as contractor reports, and it often takes a month or more to receive them. That is too long a time lag for serious inquiries. In contrast, professional society journals are available everywhere, and it is

likely that a potential user of NASA generated technology would be a regular reader of such journals.

Further, technical information is only one factor in stimulating technological innovation. Education, training and experience also play an important role in that they prepare target groups for new technologies (Utterback, 1971, p. 80). If universities and professional societies joined the screening and evaluation process, it would create an opportunity to disseminate NASA generated technology by means of training and education. In the long run this might lead to a substantial increase in technology transfer. To sum up, NASA technology could be disseminated on a much wider basis using existent and effective non-NASA channels.

o It is possible that the screening and evaluation process itself, through the participation of other organizations, would become a transfer process. This is particularly true when so-called industry "gatekeepers" join the screening and evaluation team (see also: Utterback, 1971, p. 64). This characteristic of the team approach is of substantial importance. Several studies point out that oral communication is an effective means for the transfer of innovations because it provides rapid feedback communication (see: Tushman, 1978, p. 625). However, along with this benefit, there is the possibility that NASA might lose some control of the transfer process.

o Technology transfer is a national goal and is not the exclusive responsibility of any government R&D agency alone. The aim of the transfer process is to improve the nation's

economy and is therefore the joint responsibility of all societal groups. Participation of other groups should not be judged as a shortcoming within NASA, but rather as a constructive means to enhance technology transfer.

o Concern about competition between government R&D agencies and industry is frequently mentioned. It is argued that national laboratories engage in "research on technology of commercial significance and thereby directly compete with private industry" (Hollomon, 1979, p. 39). For instance, the McNeil-Schwindler Co. protested NASA's maintenance work on NASTRAN (a NASA computer program), claiming that such work should be performed by private software houses. Evidence is also cited to the effect that commercial R&D performed by a government agency alone might be inefficient (Hollomon, 1979, p. 32; Gilpin, 1976, p. 170). A team approach would establish a forum in which the parties concerned could discuss such problems at an early stage.

o A team approach to screening/evaluation would be effective as well, due to the screening of technologies which have no value for industry. In some recent literature on technology innovation, technology, etc., the need for a team effort to promote technology innovation and technology transfer has been identified and evaluated.

3.2 Disadvantages of a team approach to screening/evaluation.

Since the early sixties, government-industry relations--enforced mainly through regulation--have been of major concern

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to both parties. All major firms now have at least one full-time Washington, D.C. representative. Industry does not passively accept government procedures. To the contrary, industry plays an active role. Established firms have large, and high-quality staffs dedicated to government relations. One of these tasks is to monitor government agencies' performance and to anticipate their future activities.

Keeping this in mind, it is rather naive to assume that industry would not use the possibility of a team approach to screening/evaluation to try to influence NASA's activities. A possible outcome would be the overidentification of NASA's work with industry's interest. Overidentification of government agencies with industries is a well-known fact. One opinion of the Federal Communications Commission (FCC) states that: "...the root of the FCC's problems is the agency's overidentification with the industries it regulates, its overidentification with the powerful and entrenched elements, in contrast to new and emerging facets or technologies, of the industries regulated" (Geller, 1975, p. 706). In this view, cause and effect are clearly described. Overidentification of a government agency with industry leads to a slowdown of technological advance. This is discussed in greater detail below.

o One of NASA's roles as a governmental R&D agency is to undertake R&D projects with high-risk, long-term pay off, high social rate of return as compared to the private rate of return, etc. Normally, private industry is unlikely to engage in such projects. The lack of private sector initiative

in the development of communication satellite technology after 1972, when NASA's efforts were curtailed, is a case in point (see: Office of Science and Technology, 1978, p. 4).

o Some of NASA's projects stem from high priority industry needs. For industry, NASA is a prime source of R&D funding. Potentially a team approach to screening/ evaluation could be misused for "doing industry's work."

o Also, the possibility of unfair technology transfer exists. If a team approach to screening/evaluation is established, NASA must offer the body of its knowledge to all participating parties.

o The team approach will only work if an appropriate climate of confidence is created. Members might not express their thoughts if they are likely to read them in the newspapers. Therefore, the team approach might not work under the conditions within which government organizations must operate. Strictly speaking, the "protection of the public interest" is critical. But it is often claimed, for example, that labor unions and "consumer representatives" should join industry committees (see e.g.: Brown, 1970, p. 31). In the past, in connection with follow-up analysis of industry's use of IAC services, NASA has experienced industry's sensitivity to information. The team approach has the potential of indicating to NASA which NASA-generated technologies are of substantial interest to industry; thereby providing a most valuable basis from which NASA can make its information dissemination

program more effective. But if the necessary condition of confidence cannot be created, the value of a team approach to screening and evaluation will only be moderate.

o In establishing procedures where other parties join the planning and decision-making of a government organization, one must recognize that the non-governmental members of the team are likely to try to shift the risk of failure to the government agency. On the other hand, NASA cannot delegate its responsibility for secondary utilization of aerospace technology to the team. If the team approach is adopted, NASA must maintain the ultimate responsibility for technology transfer.

A team approach to screening/evaluation then has advantages as well as disadvantages. The disadvantages--at least most of those mentioned above--occur by an overidentification of NASA with industry's interests. Yet, this possibility seems unlikely. Government agencies can be put in two main categories; industry-oriented (e.g. FCC) and functionally-oriented, or crosscutting (e.g. EPA). While industry-oriented agencies may be captured by the interest of the industry they regulate, this may be less likely for functionally-oriented agencies (see also: Weidenbaum, 1978, p. 10). In the secondary utilization of aerospace technology, NASA can be described as a functionally-oriented agency, with the task of transferring technology to all non-aerospace industries. The possibility of being captured by the interests of a single non-aerospace industry exists but does not seem to be a real threat.

3.3 Review of a team approach to screening/evaluation.

Only a comprehensive analysis will indicate the advantages and disadvantages of a team approach to screening/evaluation of NASA generated technology. Critical to the success of such an approach is the organizational structure which provides the basis for cooperation between NASA and the participating parties:

- o Should other participating parties serve as an advisory board to provide suggestions and recommendations, leaving decisions to NASA?
- o Should NASA be only one party among many, that is to say should NASA have no special power concerning decisions?
- o Should NASA and other parties be bound together in an advisory board and the responsibility for decisions be given to another federal organization?

These and other organizational options should be comparatively analyzed.

The advantage of a team approach to screening/evaluation is provided through the direct participation of private and governmental organizations which influence the technology transfer process. It can be assumed that the team approach has particular potential when the operations are based upon people rather than on fixed procedures. Procedures, most valuable for routine tasks, are not appropriate to the exploration of the changing factors which influence technology transfer. But this pattern

is twofold, in being dependent on the capability of the individuals joining the team, the performance of team members is a source of potential success and failure. This should be taken into account, especially in the implementation phase. It might be effective for NASA--before announcing the implementation of its team approach to screening/evaluation--to very carefully select individuals who are both capable and willing to perform the task. This selection process might best be achieved through informal contacts, keeping publicity very low. Furthermore, in case this screening/evaluation method is adopted, NASA should resist any moves to demonstrate its potential before the team is stabilized; that is to say, not until all individuals joining the team have accepted their role within the team and a climate of confidence has been created.

4. Potential members for the team.

The intention of this section is to cite and briefly describe organizations which could participate in the team approach to the screening/evaluation. Once again, only a comprehensive analysis can provide in-depth insights.

o One source of participants are industry specific R&D institutes. Besides the R&D effort of specific firms, there are often R&D projects undertaken by all (or the most important) firms within an industry branch. In some industries those R&D activities are institutionalized in the form of R&D institutes, e.g. the Chemical Industry Institute of

Toxicology. This institute is funded by the largest U.S. chemical companies and investigates the toxicology of non-proprietary chemicals (Hiss et al., 1975, p. 97). In West Germany the "Institut der Stahl- und Eisenindustrie," has performed important studies for the steel industry on the development of mathematical process models for control of blast-furnace processes.

Normally, such institutes know the characteristics of technologies already being used and those in research programs. This knowledge would be extremely useful in identifying those NASA technologies having potential value for a certain industry. Furthermore, such institutes might prove useful in aiding NASA's development of prototypes.

o Another valuable organization might be industry associations. Industry associations possess substantial knowledge about the R&D performance of the industry they represent. For example, the association of the chemical industry knows under which circumstances this industry will be willing to switch from coal to oil. Therefore, NASA is able to grasp "what is going on in industry" and to prepare appropriate transfer efforts at the right time. NASA might also gain knowledge about typical industry R&D policies. For example, in areas such as semiconductors, electronic sub-assemblies and scientific instruments, process innovations are not "manufacturer dominated" but "user dominated" (Hippel, 1976; Hippel, 1977, p. 60; Abernathy, Utterback, 1978, p. 42). In other industries, raw material suppliers or the producers

of capital goods might dominate innovative behavior. In processing such knowledge, NASA would enhance its ability to address the right target group with information about new technologies.

As mentioned earlier, NASA technology transfer managers may lack "commercial experience." With the help of industry associations NASA might be able to use commercial facts to provide useful value-added technological information.

o The possibility also exists that <u>single firms</u> might join the screening and evaluation process of NASA technology. At first glance, it seems that industry R&D line managers would be highly qualified to perform such work. But difficulties in selecting firms would undoubtedly arise. These difficulties can be avoided through the use of industry associations and professional societies.

o <u>Professional societies</u> might be a valuable organization for screening and evaluating NASA's technologies. In most cases such societies represent a substantial part of professionals working in a certain field, and they generally have good reputations. In some cases those societies already evaluate new technologies and offer education to their members concerning those technologies. Education is important. The mere existence of a technology is not sufficient; a capability to use it must be developed (Gee, 1978, p. 109).

In West Germany, starting in 1978, the Ministry of Science and Technology realized the high potential value of

professional societies. The societies perform work similar to that of NASA's Industrial Application Centers.

In an investigation about "diffusion and utilization of scientific and technological knowledge within state and local governments" it is noted that professional engineering societies, e.g. the American Society for Mechanical Engineering, are interested in becoming involved in the area of technology transfer (Feller, Flanary, 1979, p. III-41).

o In some cases it might be worthwhile to think about the possibility of including certain government agencies in the screening and evaluation process, at least on a case-by-case basis. This is due to the fact that while technologies might improve productivity or dampen inflation, they might also have side-effects for health, safety, environment, etc.

The costs of determining if a new technology will obtain regulatory authority approval can be an important factor in the introduction of innovations in technology (Hollomon, 1979, p. 33; see also: Weidenbaum, 1978, p. 17-20). If the concerned government agencies participate in the proposed screening and evaluation process of new technologies, they could facilitate the innovation process. If regulatory information were added to the technical description of a new technology, a potential entrepreneur could more readily assess its commercial prospects.

o Organizations within the university community present another possibility. There are two groups of major importance,

scientific and technology utilization personnel. Professors are a very valuable group to have join the screening and evaluation process. Furthermore, in this case it is worthwhile to consider a secondary benefit of using universities. Universities are of substantial importance as a transfer medium and would link NASA directly to the professionals of tomorrow.

One might also think about university technology utilization personnel. In recent years university administrations have explored the revenue generating value of university generated inventions (Udell, Johnson, 1978, p. 175) and by now quite a few universities are active in this area.

Conclusions

Underlying the analysis in this paper is the assumption that the NASA technology transfer could be substantially improved if the application process of technologies were better understood. NASA is successful at information dissemination, but there is a lack of knowledge about why certain technologies are adopted and other technologies are not. A comprehensive understanding about factors influencing technology transfer might indicate ways of developing improvements. By including non-federal organizations, such as professional societies and industry R&D institutes, in the screening and evaluation process of NASA generated technology, opportunities may develop to enhance technology transfer from NASA to industry.

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A SURVEY OF MACHINE READABLE DATA BASES

Peter Matlock
August 1981

Abstract

A major concern of NASA's Technology Transfer Division has been to determine how to match applications of NASA's technology with the needs and interests of non-NASA technologists and scientists. A recurrent theme in the work performed for NASA at Stanford University has been to investigate those methods which allow maximum user involvement in the selection of information deemed relevant to his concerns. This is viewed as important, since the ultimate "innovator," or "man on the bench" is the best judge of what is of use to him.

At the same time, however, it is clear that eliminating or reducing pre-selection of information leads directly to higher user costs, because the amount of information each final user must screen would be magnified enormously.

Using machine readable data bases with an interactive searching algorithm can be a means for getting information directly to those who will use it, with minimal increase in the user's costs. As an instrument of technology transfer, NASA's RECON files could conceivably play an even greater role in exposing the public to available NASA technology.

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A SURVEY OF MACHINE READABLE DATA BASES

Peter Matlock

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National Aeronautics and Space Administration

Contract NASW 3204

PROGRAM IN INFORMATION POLICY

Engineering-Economic Systems Department
Stanford University Stanford, California 94305

1. PREFACE

A major concern of NASA's Technology Transfer Division has been to determine the most effective methods for matching applications of NASA's technology with the needs and interests of non-NASA technologists and scientists. A recurrent theme in the work performed for NASA at Stanford University has been to investigate those methods which allow maximum user involvement in the selection of information deemed relevant to his concerns. This is viewed as important, since it is held that the ultimate "innovator," or "man on the bench" is the best judge of what is of use to him. Thus, minimization of unnecessary pre-screening and pre-selection by third parties better allows the ultimate user to exercise his own judgement, and to make more effective use of the information presented to him.

At the same time, however, it is clear that eliminating or reducing pre-selection of information leads directly to higher user costs, because the amount of information each user must screen is magnified enormously.

Using machine readable data bases with an interactive searching algorithm can be a means for getting information directly to those who will use it, with minimal increase in the user's costs. As an instrument of technology transfer, NASA's RECON files could conceivably play an even greater role in exposing the public to available NASA technology.

With this idea as background, this paper investigates the data base industry, and the functions that NASA already performs as a member of that industry.

2. INTRODUCTION

The growth of machine readable data bases has been rapid over the last fifteen years. Currently over 1000 computerized data bases provide information in all areas of the natural and social sciences, arts and humanities, and business and public policy. A report from International Resource Development estimates revenue from the supply and distribution of on-line data bases at $1.25 billion in 1981, with growth to $5.5 billion in 1991.[1]

This paper describes a sample of the machine readable data bases available to the technologist and researcher in the natural sciences and engineering; and compares them with the data bases and date base services offered by NASA.

The data base industry can be segmented into three categories, following the categorization of Roger Christian.[2] Christian attempted to distinguish three sectors of this industry: the publishers, distributors, and users. The problem with this simple segmentation is that one individual or firm may operate in more than one of these sectors. Distributors publish their own data bases. Publishers market to academic and special libraries, as well as to commercial vendors (who in turn market to academic and

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[1] Telecommunications Journal, March 23, 1981

[2] Christian, Roger: The Electronic Library: Bibliographic Data Bases 1975-76 Knowledge Industry Publications; White Plains, New York; 1975; page 4

special libraries). Libraries that buy a data base may compete directly with the supplying vendor or publisher. The government sells, buys, and distributes to, from, and in competition with private vendors and publishers. Finally, a publisher's own data base and printed services may compete with each other.

However, despite the often complex flow of goods in this industry, categorizing the data base industry into users, publishers, and distributors is used in this study as a useful classification of the industry.

NASA performs the functions of all three sectors in the data base industry. NASA publishes its own data bases, called the RECON/NASA files. NASA not only compiles much of these files, but publishes them in machine readable form, and distributes them to its user group through the Industrial Applications Centers (IAC's), or the State Technology Applications Centers (STAC's), or by direct dial-in access to NASA's computer center in Maryland. Finally, NASA is itself a subset of the entire user set. Much of the information on the RECON/NASA files is primarily of use within NASA, and the files are widely used by in-house researchers and scientists.

Non-NASA users have access to the RECON files either through the IAC's and STAC's, or through an arrangement whereby prime contractors with NASA may have direct on-line access to the RECON files.

3. FUNCTIONS ASSUMED BY NASA IN THE DATA BASE INDUSTRY

In the machine readable data base industry, NASA not only serves the functions of publishing, distributing, and using its own data bases, but was responsible for developing RECON. RECON is an interactive index and text searching system, which was the precursor to Lockheed's current DIALOG system. Through RECON, users can search several types of data files. These files are listed in Table 1, which gives the number of entries as of July 1, 1980:

Approximately 70% of the RECON entries are comprised by STAR and IAA. Entries in STAR include: NASA, NASA contractor, and NASA grantee reports; reports of other government agencies, univisities, private firms, and domestic and foreign institutions; translated reports; NASA owned patents and patent applications; and dissertations and theses. STAR covers all aspects of aeronautics and space research and development; related basic and applied research; and applications including earth resources, energy development, conservation, oceanography, environmental protection, urban transportation, and topics of national interest.

Entries in IAA include: periodicals (including government sponsored journals); books; meeting papers and conference proceedings of professional and academic societies; and translations of journals and journal articles. The subject matter is aeronautics and space science and technology.

TABLE 1

DATA FILES ON THE RECON DATA BASE

As of July 1, 1980

Document files

Name	Description	Number of Entries	Percentage of Total
STAR	Scientific and Technical Aerospace Reports	453,000	29.4%
IAA	International Aerospace Abstracts	609,000	39.6%
OSTARE	"Old" STAR	148,000	9.6%
LSTAR	Limited STAR	81,000	5.3%
CSTAR	Confidential STAR	144,000	9.4%
Others	Tech Briefs, some ASRDI	104,000	6.7%
Total		1,540,000	100.0%

Special Files

Name	Description	Number of Entries
CPA	Computer Program Abstracts	2,300
R&DCS	NASA Contract Directory	14,600
RTOPS	Research and Technology Operating Plan	7,000
ASRDI(Fire)	Safety File--Fire	4,000
ASRDI(Cryo)	Safety File--Cryogenics	7,000
ASRDI(Mech/Struc)	Safety File--Mechanical and Structural	900
Tech Briefs	Tech Briefs	8,300

NALNET
(NASA Library Network)

Subject	Availability	Number
Books	NASA Holdings	74,000
Books	MARC Tapes	270,000
Periodicals		7,600

Other files on the RECON system include OSTARE, which is

similar to STAR, lists unclassified documents, and is older than STAR. The R&DCS, or NASA Contract Directory, provides the contract number, technical monitor, center, and principal investigator for NASA contracts. The RTOP file lists current and older RTOP's, which are program plans between NASA Headquarters and the NASA Field Centers. The collection of ASRDI files is referred to as the "Safety File," and lists reports collected by the Lewes Research Center addressing safety issues in each of the listed areas. Finally, the Tech Briefs file lists NASA technology available for commercialization, and contains most of the information in the print version of _Tech Briefs_. The hardcopy _Tech Briefs_ has traditionally served as a major vehicle for transferring information concerning NASA technology to the private sector, and as result there seems to be greater public exposure to the hardcopy _Tech Briefs_ than to the machine readable version.

Some of these data files, in particular the ASRDI, NALNET, RTOP's, and R&DCS files, may be of little interest outside the community of NASA personnel and associated contractors. However, other files, such as STAR, IAA, CPA, and the Tech Briefs may be of considerable utility to engineers and technologists outside this community.

Historically, there has been public (non-NASA) access to these files through either of two avenues. Those members of

the public who are not prime contractors with NASA may submit a search request with a regional IAC or STAC, and the NASA staff will perform the search. This branch of the Technology Transfer Program offers machine and manual searching, historical as well as Selective Dissemination of Information (SDI)--or Current Awareness--searching, and the support staff to interpret and analyze the results of the search.

Prime contractors with NASA may obtain on-line use of the RECON files under a development program to allow greater numbers of users dial-up access to the RECON system. In the past, the number of direct access dial-up ports that RECON's computer could handle has been severely limited. A new front-end processor and larger computer will greatly enhance capacity. As an example of the advances made in expanding its capacity and response, it is reported that RECON response time is down to about two to two and one-half seconds, as opposed to the approximately 26 second average wait in the early stages of the system.[3]

Although much of the file content of NASA's RECON may only be directly pertinent to those closely connected with NASA, there is a substantial amount of information that may be useful outside NASA. <u>Spinoff 1979</u> makes the point that

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[3] Figures based on a conversation with Mr. Bill Brown of NASA.

through the IAC'S and STAC's, a non-NASA inquirer has access to over 10 million documents, and of these, 1.5 million are in NASA/RECON. In all, approximately 15,000 scientific and technical journals worldwide are covered, as are publications from other government agencies.[4]

Thus, NASA's data base answers technical and reference questions for non-NASA users and NASA users and contractors, and also serves as an internal research directory for the community of NASA employees and contractors. In terms of technology transfer, NASA uses machine readable data bases to transmit information to private sector technologists through two avenues. One avenue has been mediated through the IAC's and STAC's, and the other is direct and conditional on the prerequisite of being a NASA prime contractor.

One question which can be raised immediately, in light of NASA's plans of expanding RECON capacity and access, is: to what extent have system limitations led NASA to treat the RECON files as a "private resource?" Limited access to RECON through IAC's and STAC's is an efficient distributional procedure when hardware limitations prevent large numbers of dial-up ports. If a "peak load" of independent users cannot be met satisfactorily by a constrained system, then it is obviously more efficient to

[4] Spinoff 1979, NASA's Office of Space and Terrestial Applications; page 112. Figures are for 1979.

force all system demands to be spread out over time. A reasonable mechanism for doing this is to channel all, or almost all system demand through agents who will meet each particular demand sequentially. It appears that the IAC's and STAC's have performed this role quite effectively. As the capacity of the RECON system is expanded, it may well be worth emphasizing the other services offered by these NASA Technology Transfer agents, as the importance of their role as intermediaries to RECON can be diminished.

This matter will be dealt with again, following a discussion of a sampling of the machine readable data bases available to private sector technologists in the non-NASA sector.

4. A SAMPLE OF PUBLICALLY AVAILABLE MACHINE READABLE DATA BASES

A sample of data bases was made to compare the scope of coverage and services offered in the machine readable data base industry with that offered through NASA's RECON. The sample was limited to technical and scientific data bases, as these were assumed to be of greatest interest to private sector scientists and technologists. The comparison was made on the basis of subjects covered, type of information recorded in the data base, source of information recorded in the data base, number of years covered, quantity of information and annual additions to the data base, approximate yearly charges for acquisition or lease of the data base, and associated cservices.

The sample comprised 42 data bases, and was drawn from a master list of scientific and technical data bases. The master list was assembled from _Information Market Place 1978-1979_, which was selected as principal reference document. _Information Market Place_ is a relatively current and complete international compendium of information sources that are publically available. Appendix A is a copy of the Table of Contents of _Information Market Place_, which is included to illustrate the document's scope of coverage.

In selecting the information sources to be included in their document, the editors of _Information Market Place_

followed a narrow definition of what constitutes information products and services. Their definition reads as follows:

> Emphasis is on those organizations which, by the application of advanced technologies, create and gather information and add value by performing one or more of the following operations: organizing it, rearranging it, adding other facts, making it more available, or by converting it into a new medium.[5]

Guided by this definition, the editors claim to have undertaken extensive research to locate all agencies and organizations involved in providing information products and services internationally. Upon identifying these organizations, the editors mailed them questionnaires inquiring into their principal and related products and services. Most of the descriptions in the final directory appear to have been self-selected. Apparently, the questionnaire was composed of a series of descriptions, and lists of pre-selected subject areas which were merely to be checked off by the respondent. Certain phrases and combinations of words were repeated quite frequently, particularly in describing the subject areas of the data bases. It is presumed that this is indeed how the information was collected, and this raises the question of how well the descriptions fit the actual content and services of the data bases and data base companies.

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[5] Information Market Place 1978-1979, page vii

On one hand, this procedure made all respondents look at the same questionnaire with the same questions and categories, and therefore lends a degree of uniformity to the final descriptions of data bases and data base services. This should aid in the comparability of these descriptions in Information Market Place.

On the other hand, with this procedure's reliance on self-reporting, there is the possibility that each respondent interpreted the questionnaire subjectively, although the degree to which one can impose subjective interpretation to words which are generally well defined through industry-wide use appears minimal. It is more likely that variation in the quality of reported information could occur because of varying individual perceptions concerning the expected utility and likely return to contributing to this directory. One can never be sure to what extent respondents presented an exaggerated image of their data base and data base services while perhaps trying to take advantage from some free advertising, or failed to adequately describe their data base and services because they thought this endeavor one not likely to pay off. One can only speculate on the extent of these effects, if they exist at all.

However, with a high voluntary participation rate among American data base publishers, and with certain indications

that data base services were insufficiently described, it appears that data base publishers perceived the directory to be in their own interest, and that these publishers did not exaggerate the extent of their data base coverage and data base services.

If a data base publisher did not return their questionnaire, the editors of the <u>Information Market Place</u> directory performed their own research and presented only the results of this research in the directory, with a note to that effect. Thus, it was possible to measure the participation rate among publishers who had been contacted by <u>Information Market Place</u>. For American companies this rate was 100%, and for all companies internationally the rate was 67%. As only American data base companies were included in the sample discussed in this paper, one can surmise that American companies saw this directory to be in their own interest, and that non-response of the publishers is not a problem for the sample discussed here.

Evidence that the publishers did not exaggerate the extent of their data base and data base services can be observed in the reported services that publishers provide in association with their data bases. For example, it was reported that 54% of the data base publishers offered "machine searching" as a service, whereas only 12% offered "retrospective searching." It seems illogical that there

would in fact be such a high discrepancy, especially since most on-line searches access several years of data. It seems more likely that the services actually performed by data base publishers were somewhat under-reported, or that there was ambiguity in the descriptive labels used in the questionnaire. In either case, the sample discussed in this paper will present only an incomplete picture of any single publisher, although the overall picture across all publishers should be adequate.

4.1 THE SAMPLE

There is a section of Information Market Place that lists machine readable data bases which are publically available worldwide. A "data base" is defined in this directory as a "collection of machine readable records which are periodically updated and which can be processed on computers with the appropriate software."[6] The editors of Information Market Place described approximately 406 data bases in this section, and these included technical and non-technical, domestic and foreign data bases.

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[6] Information Market Place, page 36

The sample of technical and scientific data bases was collected in two steps. First, all the technical and scientific domestically produced data bases were selected. This was done by a process whereby the author made two passes through the list. In the first pass the author eliminated all data bases whose descriptions did not include areas related to the natural sciences and traditional technical fields. A second pass was made to provide a higher degree of objectivity to this process. This second pass took advantage of a subject index of data bases which is included in Information Market Place. Scientific and technical subject areas were selected, and the data bases listed under each subject heading were cross-checked against the first selection to ensure that there were no omissions. Appendix B contains a list of the subject areas checked.

This procedure resulted in a list of 128 domestically produced data bases that could be of direct interest to a private sector scientist or technologist. Of course, it is always possible that certain data bases, such as the financial data bases, or indices of industrial production, or even the listings of historic homes, could be of direct interest to these scientists and technologists. It is even more likely that certain foreign data bases, such as the European Space Agency's Space Components File, or the Carbon-13 Nuclear Magnetic Resonance CMR, or Hydromechanics and Hydraulic Engineering, would be of direct interest.

This is an important point, since some foreign data bases, such as Aquatic Sciences and Fisheries, are available on-line through services such as Lockheed's DIALOG. However, as specified before, non-technical or foreign data bases were omitted. An expanded study should attempt to identify other types of data bases which could be relevant, and which play a significant role in the data base industry, as perceived from the American viewpoint.

The working sample was selected from this list of 128 alphabetically listed data bases by taking every third listed data base. There was an early oversight in that the Paris-based Aquatic Sciences and Fisheries was originally included in the working sample. This was replaced by the first entry on the master list, which was the API Tech Index.

Summary information on each data base was then collected from <u>Information Market Place</u>, and this information was supplemented by data from certain annual reports, the publication <u>Computer Readable Data Bases: A Directory and Data Sourcebook</u>, and from <u>Excerpts from Directory of On-Line Data Bases</u>. The basic information collected for each data base included its name, publisher, type of coverage (whether each data entry is bibliographic or non-bibliographic, with a description), fields of coverage, years covered, number of entries as of 1978 and number of annual additions, and where

the data base is available if available on-line. Appendix C lists the names of the data bases in the sample, and the publisher of each data base.

Entry 30 in Appendix C is RECON/NASA, which is listed as available through the Knowledge Availability Center, University of Pittsburgh. The RECON/NASA data base is described as bibliographic (listing citations), with multidisciplinary coverage of engineering, science, and project management. It covers the years since 1962, had 720,000 entries in 1978 with 55,000 annual additions and is not listed as being available on-line to the public.

The description of the RECON/NASA files in Information Market Place differs from that given in Spinoff 1980, because the Information Market Place description is only for the Knowledge Availability Center (the Pittsburgh "IAC"). Each IAC essentially has its own procedure for using the RECON system, with the New England Research Applications Center (NERAC) even producing its own tapes. The description of RECON in Information Market Place is in fact a description of information services the Pittsburgh IAC offers, rather than a complete description of the NASA/RECON system.

This discrepancy is of interest, because it appears that the extent of services available through the IAC's and STAC's, as well as the scope of RECON/NASA, are both being

under-reported in a reference document such as Information Market Place. With this insight into the manner in which data bases were described in Information Market Place, the characteristics of the data bases selected in the sample can be discussed. The results will be examined to assess the nature of publically available scientific and technical data bases.

4.2 RESULTS AND DISCUSSION

Information Market Place classified the data bases as either bibliographic or non-bibliographic. A bibliographic data base was intended to supply full bibliographic information of a published document. A non-bibliographic data base supplied specific data, component specifications, descriptions, or non-published reports. Information Market Place did not supply detailed definitions on the difference between these two types, but an article by Doszkocs, Rapp, and Schoolman discussed the types of available data bases in greater detail.[7]

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[7] Doszkocs, Rapp, Schoolman, "Automated Information Retrieval in Science and Technology," Science, April 4, 1980, pages 25-30

Their discussion of bibliographic data bases, data banks, and the emerging "knowledge" data bases helps clarify the classifications used by Information Market Place. These authors cited bibliographic data bases as those referencing published literature, and which are used most often to locate an article or document. These tend to be computerized versions of existing indexing and abstracting services. Examples include Engineering Index, Science Citation Index, and Government Reports Announcements Index. Non-bibliographic data bases include what these authors refer to as "data banks" and ""knowledge bases." Data banks contain numeric and analytical data obtained from published literature, and often reference the source of information. Examples include the National Library of Medicine's Registry of Toxic Effects of Chemical Substances and Toxicology Data Bank; and the Laboratory Animal Data Bank. The former two contain toxicological, chemical, and pharmacological data for approximatley 36,000 substances (listed by all their names and synonyms, and including their formula), and the latter provides husbandry conditions and physiological and pathological baseline data for laboratory animal groups, and allows interactive statistical analysis. Data from the former two data bases comes from published literature, whereas data for the latter is obtained directly from participating laboratories. Finally the authors discuss the "knowledge data bases," which they compare to

encyclopedias or textbooks. These data bases, such as the Hepatitis Knowledge Base, represent an analysis and synthesis of available knowledge. These examples help illustrate the difference between bibliographic and non-bibliographic data bases.

When the data bases in the sample were analyzed for the relative number of bibliographic and non-bibliographic data bases, the classification of Information Market Place was used. This classification was generally in agreement with that of Doszkocs, Rapp, and Schoolman. 21 of the data bases in the sample were described as bibliographic and 21 were not. Although the numbers need not be exact due to certain definitional problems, there does seem to be an even split between bibliographic and non-bibliographic data bases.

The data bases were then cross-tabulated by bibliographic versus non-bibliographic coverage and multiple versus single field coverage. A data base was defined as having multiple field coverage if its subject area included more than one separate field, even if those fields are related. A data base with single field coverage had, obviously, a subject area in only one distinct field.

As an illustration of this cross-tabulated classification scheme, consider the following examples: Maritime Research Information Service (MRIS) counted as a bibliographic data base with multiple field coverage, since Information Market

Place listed it as "bibliographic," indexing technical reports, journals, and conference papers. Its listing of multiple fields included marine transportation, pollution, business, chemistry, law, metallurgy, and twelve other categories. Cancerproj counted as a bibliographic data base with single field coverage, as it is described as a bibliographic listing of current cancer research projects, and its coverage is limited to researchers, organizations, and funding sources involved in cancer research, and to descriptions of that research.

A non-bibliographic data base with multiple field coverage was the Total Marketing Analysis Research Service, which is a "full text database" listing contract awards by the Department of Defense, and which covers Aerospace and Aeronautical Engineering, Agriculture and Agricultural Engineering, Biology, Business, Economics and Management, and Electronics and Electrical Engineering. Any of the Cordura Publications, Inc. data bases may serve as an example of a non-bibliographic data base with single field coverage. For example, one of these data bases is called Discontinued Thyristor, which provides engineering and purchasing information about discontinued models of this particular electronic component. Its field of coverage is discontinued thyristors exclusively, providing performance specifications, engineering data, type numbers, and manufacturers.

The results of this cross tabulation are shown in Table 2 Note that the data bases are split evenly between those with multiple versus single field coverage, as well as those that are bibliographic versus non-bibliographic.

TABLE 2

DISTRIBUTION OF DATA BASES

Cross Tabulation:
Bibliographic vs. Non-Bibliographic,
By
Multiple vs. Single Field Coverage

Coverage	Bibliographic	Non-Bibliographic
Multiple Field	17	4
Single Field	4	17

Again, although the numbers may not be exact due to definitional problems, there does seem to be a tendency for bibliographic data bases to cover multiple subject fields, and for non-bibliographic data bases to cover a single subject field.

Perhaps this result is not altogether surprising. One would expect a non-bibliographic data base to serve a well defined (i.e., single subject) field, since by nature it is oriented towards this. Somewhat more surprising is the finding that most bibliographic data bases cover multiple subject fields, as there is no a priori reason for this to

be so. One possible explanation is that bibliographic data bases may serve general research or literature reviewing purposes. For these purposes, a bibliographic data base covering a single subject field could be too narrow to be practical.

As an illustration of this problem it is interesting that the Stanford University Engineering Library's principal librarian found that performing an interdisciplinary search on Lockheed's DIALOG system posed a major difficulty. The problem was that too many of the system files (individual data bases) had to be referenced to cover all the relevant material and subject areas desired. In this example, it could be said that the DIALOG system data bases still do not cover enough fields. Enhancements to the DIALOG system currently enable users to search a small set of files simulataneously, and this is the first step towards the ability to perform simultaneous interdisciplinary searches on multiple data bases.

This question of the content and structure of a data base could be relevant to NASA, particularly if NASA were to consider aggressively tailoring RECON files to users' needs, as more users have the opportunity for direct dial-up access to RECON. The first step in this process would be to identify those potential users and their needs, and determine if NASA's files are of appropriate content and

structure. Of course, as long as only NASA prime contractors have this access, there is a high probability that no file modifications would be necessary. Most NASA prime contractors and NASA personnel are, after all, in closely related areas of work.

A footnote to this discussion is that seven of the seventeen non-bibliographic single field data bases were produced by Cordura Publications, Inc. These data bases were: Discontinued Diode, Discontinued Thyristor, Elastomers, Interface Integrated Circuits, Linear Integrated Circuits, Microwave Tubes, and Optoelectronics. All of these provided specific technical and production information in electronics and materials. These appeared the most specifically targeted data bases in the sample. Judging from Cordura's 1978 and 1979 Annual Reports and the Value Line Survey, these data bases have been quite successful for Cordura, and are the company's most profitable and promising enterprises. Cordura's data bases are an example of targeted computerized information banks, which are valued enough by scientists and technicians that they are commercially successful.

The source of the information listed in each data base is described in Table 3. Table 3 was derived from the publication, Computer Readable Data Bases: A Directory and Data Sourcebook, and data was available for 22 of the data

TABLE 3

SOURCE OF INFORMATION LISTED IN DATA BASE
BY DATA BASE, IN PERCENTAGES

	Journal Articles	Gov't. Reports	Patents	Monograms, Conference Proc. Theses	Reprints, Conference Papers	Manufac-turer's Catalogs	Press Rpts. Broadcasts Releases	Other
1. API Tech. Index	93	1	0	1	5	0	0	0
2. Agricola	90	0	0	10	0	0	0	0
3. Biosis Previews	94.8	.2	0	5	0	0	0	0
4. CA Condensates	72	2	16	10	0	0	0	0
5. CA Subject Index	72	2	16	10	0	0	0	0
6. Cancerproj	0	0	0	0	0	0	0	100
7. Chemical Abstracts Service Source Index	0	0	0	0	0	0	0	100
8. Chemical Industry News	100	0	0	0	0	0	0	0
9. Clinprot	0	0	0	0	0	0	0	100
10. Conference Papers Index	0	0	0	0	0	0	0	100
11. Defense Market Measures System	0	0	0	0	0	0	0	100
12. Drug Product Information File	98	2	0	0	0	0	0	0
13. Energy Line	44	42	0	3	9	0	1	1
14. Food and Agricultural Chemistry	74	1	15	10	0	0	0	0

15. Geological Ref. File	70	3	0	20	6	0	0	1
16. Maritime Research Information Service	67	25	1	2	2	0	0	3
17. NASA/RECON	0	90	1	1	1	0	0	7
18. Pharmaceutical News Index	0	0	0	0	0	0	0	100
19. Polymer Science and Technology	48	1	50	1	0	0	0	0
20. Science Citation Index	100	0	0	0	0	0	0	0
21. TTD Keyterm Index	54	1	30	4	1	4	0	6
22. Transdex	0	100	0	0	0	0	0	0

bases. Of the data bases listed, only Bell and Howell's Transdex was comprised of a higher percentage of government reports than was NASA/RECON. 100% of the Transdex entries were listed as government reports, whereas for NASA/RECON this figure was 90%. Energy-line was a distant third in this ranking, with 42% of its entries coming from government reports.

The high percentage of government reports listed in NASA/RECON set RECON apart from the remaining data bases. 82% of these data bases had 3% or less of government reports, 50% had 65% or more of journal articles, and 27% had 100% "other." Thus, NASA is in a distinct minority in terms of its high percentage of government reports. Whether this is perceived by potential users to be an advantage or disadvantage is unanswered, but is obviously important in terms of "marketing" the RECON system.

Table 4 shows the distribution of data bases insofar as the first year of coverage is concerned: No clear trend by five year grouping is apparent, although there does seem to be a growth by decade (10 prior to 1960, 13 in the 1960's, and 17 in the 1970's).

Table 5 illustrates the distribution of data bases by their number of entries in 1978. The largest data base in the sample was the CA (Chemical Abstracts) Subject Index Alert, with 17,896,000 entries. Other large data bases were

TABLE 4

DISTRIBUTION OF DATA BASES

By First Year of Coverage

First Year of Coverage	Number of Data Bases
Prior to 1960	10
1960-1964	7
1965-1969	6
1970-1974	11
1975-1979	6

the Science Citation Index with 5 million entries, and CA Condensates with 3,133,600.

TABLE 5

DISTRIBUTION OF DATA BASES

By Number of Entries, 1978

Number of Entries	Number of Data Bases
Less than 100,000	22
100,000-500,000	10
500,000-1,000,000	4
1,000,000+	6

The distribution of the 22 smaller data bases (those with 100,000 entries or less) is exhibited in Table 6 Eighteen of these twenty-two smaller data bases had less than 50,000 entries. Figure One plots the number of data bases on a log scale of size. The distribution is

Figure One

Distribution of Data Bases
By Number of Entries, 1978
Log scale for number of entries

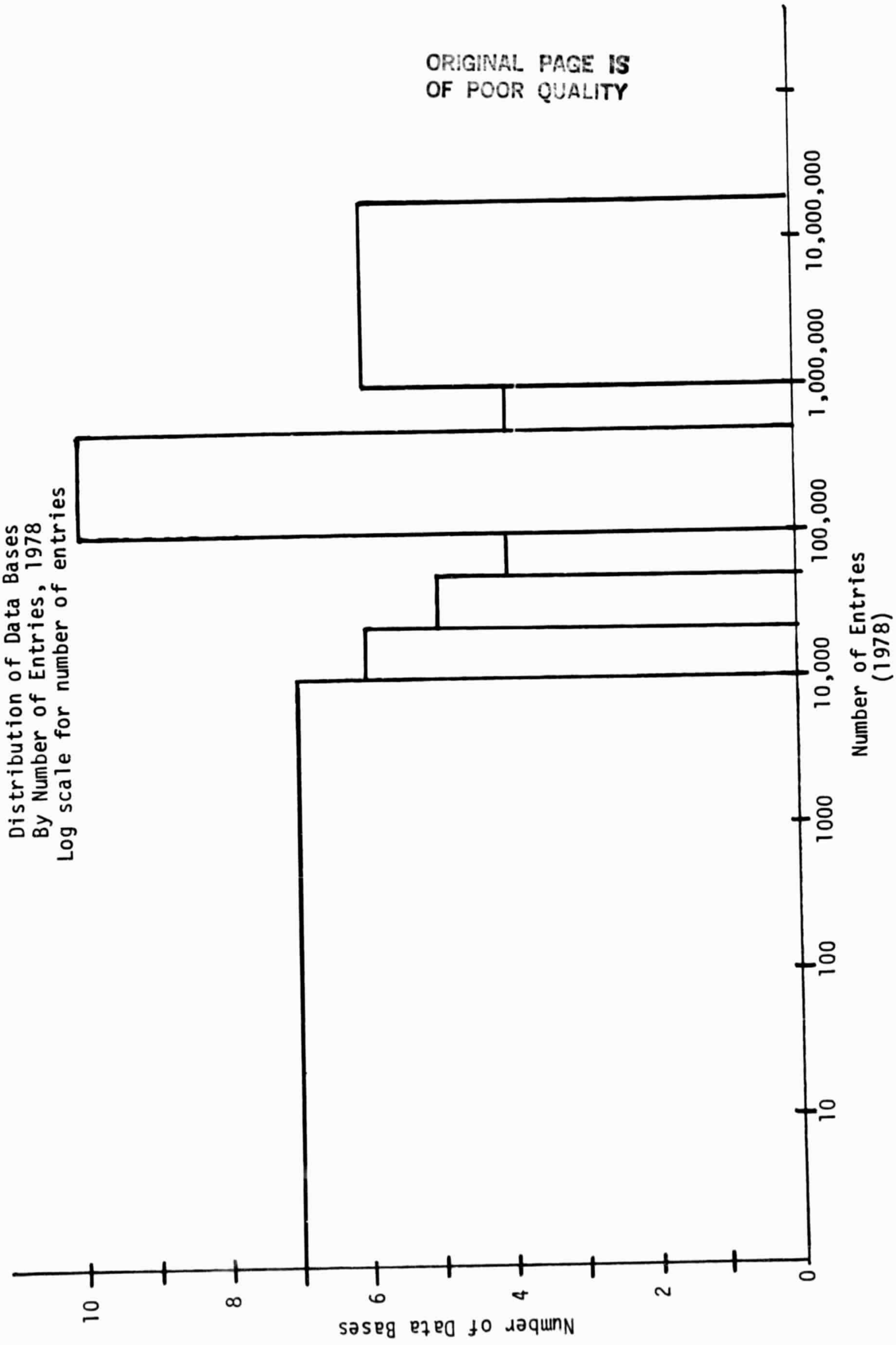

TABLE 6

DISTRIBUTION OF DATA BASES

By Number of Entries, 1978
Less Than 100,000 Entries

Number of Entries	Number of Data Bases
Less than 10,000	7
10,000-20,000	6
20,000-50,000	5
50,000-100,000	4

essentially constant, at a level of approximately six data bases for each size grouping. It should be noted, however, that most of the data bases with less than 10,000 entries were the highly-specialized, non-bibliographic Cordura Publications Inc. data bases, as well as the extremely small ARPANET Requests for Comments (which is essentially an on-line suggestion box).

Table 7 provides the distribution of data bases with respect to the number of annual additional entries:

TABLE 7

DISTRIBUTION OF DATA BASES

By Number of Annual Additional Entries

Number of Annual Additional Entries	Number of Data Bases
Less than 50,000	24
50,000-100,000	6
100,000+	4

This distribution is represented in Figure Two, which plots the number of data bases on a log scale of the number of annual additional entries. In contrast to the plot of number of entries (Figure One), the plot of number of annual additional entries does not appear constant. The data base with the largest number of annual additions was the CA Subject Index Alert, with 2,600,000 additional entries annually. CA Subject Index Alert was also the largest data base in size as of 1978. Data was not available for every data base.

Data representing the consumer's price to acquire, lease, or license each data base was collected from Computer Readable Data Bases: A Directory and Data Sourcebook. This data was used to try to estimate a first order relation between the "price" charged for each data base and a data base characteristic that in theory would contribute to the cost of producing the data base. In this paper the size of the data base and the number of annual additions to the data base were selected as characteristics hypothesized to most likely affect the price charged to data base users.

The desired result is to test whether price charged for a data base equals the marginal cost of producing that data base. The marginal cost of producing the data base is approximated by a simple cost function with a single data base characteristic as its argument. One would prefer time

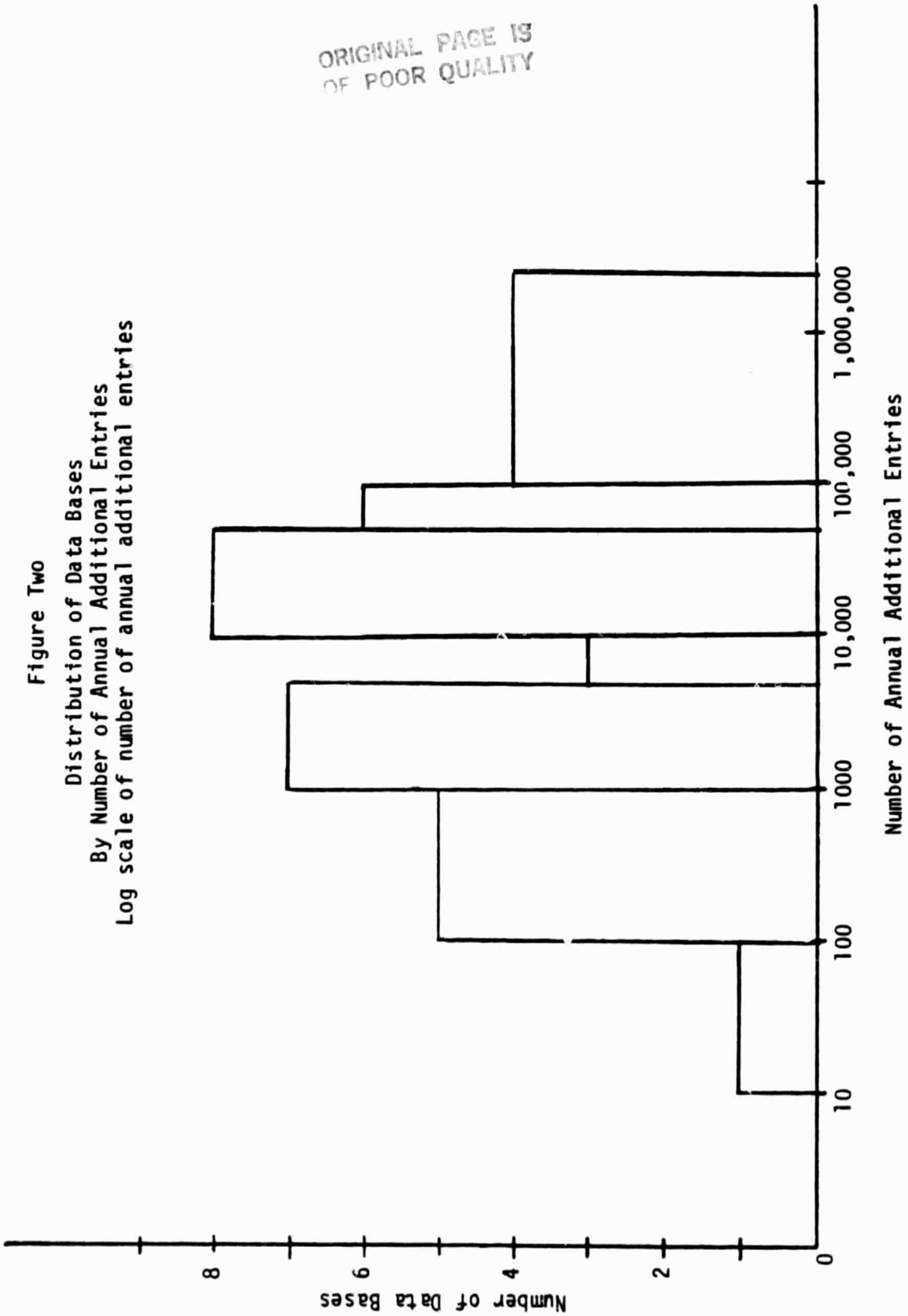

Figure Two
Distribution of Data Bases
By Number of Annual Additional Entries
Log scale of number of annual additional entries

series data for each data base to perform this measure, but only a cross sectional sample for one year is available. Furthermore, the "price" variable is not an equivalent measure for each data base. The figures reported were for either acquisition, lease, or license of the data base. For simplicity the acquisition price was treated equivalently to one year's lease or license price, even though an acquired data base would provide additional years of service at no additional yearly charge, but additional years of service from a leased or licensed data base would incur such charges. Finally, only the user's "fixed" costs of gaining initial access to a data base's information were considered. Most of the leased or licensed data bases charged an additional hourly search charge, or "variable" cost to the user. These additional costs were not considered.

The first set of regressions were to determine if there were a relationship between the size of the data base and the price charged the user. Simple regressions were run for the seventeen data bases for which information was available, and then for data bases classified either as private, or non-profit and government. F Tests on each regression showed that none of them were significant at the 90% confidence level. Results are below:

$$y = mx + b$$

y = acquisition, lease, or license costs

x = number of data base entries

All data bases:

(1) $y = .0023x + 3630$

$N = 17$

$F(1,15) = 3.466$ insignificant

Private data bases:

(2) $y = .0019x + 6031$

$N = 11$

$F(1,9) = 1.316$ insignificant

Government and non-profit data bases:

(3) $y = -.0007x + 1450$

$N = 6$

$F(1,4) = .676$ insignificant

Regressions were run with the number of annual additions to the data base as the independent variable, to see if this variable might not be a proxy for marginal costs, and produce a correlation with the data base price charged. There were insufficient data points to do this for data bases produced by government and non-profit organizations,

so the regressions were only performed on all 13 data bases for which there was data, and for the 11 private ones. All regressions were insignificant at the 90% confidence level.

$$y = mx + b$$

y = acquisition, lease or license costs

x = number of annual additions to data bases

All data bases:

(4) $y = .0186x + 4322$

$N = 13$

$F(1,11) = 1.632$ insignificant

Private Data Bases:

(5) $y = .0171x + 5033$

$N = 11$

$F(1,9) = .9962$ insignificant

The insignificance of these regressions may be attributed to any of the following reasons:

1. Misspecification of variables
2. Errors in the data
3. Misspecification of the model
4. Misspecification of the functional form
5. Lack of any true relationship

Possible misspecification of the variables and errors in the data have already been discussed, and a correction for possible heteroskedasticity (problems with correlating variables from data bases of different sizes) yielded no better results. The simple regressions used here may not reflect all the costing and pricing complexities that actually occur, indicating an inaccurate model. The functional form of these relationships may not be linear, but an experiment with log forms did not improve results. Finally, it is possible that there is no true relationship between these variables, although the argument for this on the basis of current evidence is weak. If there were to be no true relationship, however, economic questions would arise concerning the extent of potential inefficiencies in the still young machine readable data base industry.

Twenty of the forty-two data bases were listed as being publically available on-line, through services such as Lockheed's DIALOG. The most commonly cited on-line service was Lockheed's, but the following were also listed: System Development Corporation's (SDC's) ORBIT, the National Library of Medicine's MEDLINE (MEDLARS on-line), the Bibliographic Retrieval Service (BRS), Triangle Universities Computation Center, General Electric Mark III, and Drilling Activity Analysis System. It would be fallacious to assume

that the twenty-two data bases for which no on-line vendor was listed are not available in some on-line capacity. For example, Cordura Publications, Inc. offers on-line service to its data bases through a contractual agreement. Although this type of service is quite different from the "data base supermarket" service offered by Lockheed,[8] SDC, or BRS, it is still an on-line service.

It may be that some data bases can still be accessed only by batch methods. Further investigation would be required to determine the exact percentage of data bases available on-line. However, it is instructive that in the Doszkocs, Rapp, and Schoolman article cited earlier, the authors note that the majority of the 528 bibliographic data bases they are familiar with can be searched on-line.[9] The authors make no mention of the proportion of non-bibliographic data bases available on-line, but one would expect this proportion to be high due to the nature of these data bases and their use.

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[8] See Appendix D

[9] Doszkocs, Rapp, and Schoolman: ibid. page 25

5. DATA BASE PUBLISHERS

Information on the publishers of the data bases in the sample was obtained by referencing the "Database Publishers" section of Information Market Place. Twenty-six publishers were responsible for the forty-two sample data bases, and their names are listed in alphabetical order in Appendix E. Information was collected for each publisher, and this information included the total number of machine readable data bases and associated print products produced, and the availablility of special training sessions, additional publications, and customized services.

The twenty-first publisher listed in Appendix E is the NASA-IAC/Knowledge Availability Center. It is described as publishing two machine readable data bases, and no printed associates to these data bases. Special services include seminars and workshops by arrangement through the marketing department, machine and manual searching, selective dissemination of information (SDI, or "current awareness" searching), analytical reports, and technical specialists to clarify, summarize, and analyze the results of a search. This list can already be seen to be incomplete, for Information Market Place does not describe NASA as offering retrospective searching. "Retrospective searching" seems to have been a standard category in Information Market Place's questionnaire, so it should have been listed. This service is described as a NASA service in Spinoff 1979[10]

Of the twenty-six data base publishers, there were private profit and non-profit organizations, governmental agencies, and the United Nations. Not enough was known about the financing of these publishers to determine their relative numbers, but it seemed that the private organizations were the majority.

Table 8 illustrates the distribution of data base publishers by the number of machine readable data bases they produce:

TABLE 8

DISTRIBUTION OF DATA BASE PUBLISHERS

By Number of Machine Readable Data Bases Published

Number of Data Bases Published	Number of Publishers
One	7
Two	5
Three	8
Four - Nine	3
Ten or More	3

The three publishers producing more than ten computerized data bases are Cordura Publications Inc. with 26, Chemical Abstracts Service with 14, and the National Library of Medicine with 12. Twenty of the twenty-six data base publishers were responsible for three or fewer data bases. Thus, the industry seems to be characterized by a large

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[10] Spinoff 1979, page 112

number of publishers who produce a small number of data bases, and by a small collection of publishers that produce a large number of data bases. Appendix F discusses a possible economic model to analyze this finding, and raises issues for further investigation.

The final table in this survey of data base publishers is a summary of data base related activities undertaken by the publishers. Table 9 lists the number of data base publishers that engage in the activity or service listed (numbers include the NASA facility). Those entries marked by an asterisk indicate NASA-IAC/Knowledge Availability Center activities, as reported in Information Market Place.

The first comment to be made on these results is that no definitions for the listed categories were provided. Thus, there may not necessarily be a clear distinction between certain of the categories. Furthermore, it is questionable that these descriptions are complete. As discussed previously, this data appears to have been completely self-reported by the respondents. Thus, there is reason to question the consistency of the responses. It is likely that if these activities were well defined, and if one interviewer had evaluated the activity of each publisher, then the numbers in some categories would be higher. For example, if 14 publishers engage in "machine searching" of data bases, it would seem likely that more than three engage in "retrospective searches."

TABLE 9

NUMBER OF DATA BASE PUBLISHERS

Engaging in Listed Activity

Activity	Number of Data Base Publishers
Publishes Print Products (often a paper version of the machine readable data base)	20
Training Programs	4
* Seminars and Workshops	14
User's Guide	6
Newsletter	4
* Machine Searching	14
* Manual Searching	8
Retrospective Searching	3
* Selective Dissemination of Information	9
Document Delivery	8
Facsimile Service	2
* Analytical Reports	5
Indexing	10
Telephone Interviewing	4
Thesaurus for Indexing	2
On Line Document/Hardcopy	1
* Access to Technical Specialists	5
Technical Conference Support	1

However, despite the potential problems cited above, one can note three items of interest. First, in providing "technical specialists to analyze and sum results, and to clarify questions," NASA is one of only five publishers listed that offer this type of customized service.

Second, only the ARPANET Network Information Center provided on-line document/hardcopy reproduction. Eight publishers (not including NASA) provide document delivery--such as the Institute for Scientfic Information.

Except for these efforts, however, on-line access to documents remains a rare service.

Third, the NASA IAC/Knowledge Availability Center and the Petroleum Information Corporation were the only publishers to offer both analytical reports and access to technical specialists. This indicates that NASA's coupling of analysis by technical specialists with its data base is a relatively unique service in the data base industry.

6. DISTRIBUTORS OF MACHINE READABLE DATA BASES

This study was not oriented towards the analysis of machine readable data base distributors, except insofar as previous discussions have addressed this section of the data base industry. Historically, the IAC's have been the access point to RECON/NASA for all non-NASA users. With dial-up access to RECON being provided for more and more users, the role of the IAC's could change. It is important to clarify who will have dial-up access to RECON (it may never be unviversal), and to what extent this will change the nature and extent of the IAC's "clientele."

A parallel question is what the effects on the IAC's role would be if a machine readable version of the Tech Briefs were offered through a distributional vendor such as Lockheed, SDC, or BRS. An analysis of these effects is conditional, of course, on the extent to which one believes there would be a commercial market for this information. If there were little market potential, then no commercial vendor would offer such a file through their system (barring subsidies).

Although it is not the intent of this study to investigate future strategies for the IAC's, it does seem important to recognize that certain developments in the access to RECON/NASA's information could impact the role played by these institutions.

7. CONCLUSIONS

1. Technical and scientific data bases cover a wide range of material through a wide variety of formats, scope, and sizes. Of note is the finding that bibliographic data bases tend to cover multiple subject areas, whereas non-bibliographic ones tend to have single field coverage.

2. RECON/NASA contains some information of minimal use to those outside NASA. However, for that information that is of non-NASA interest, NASA data bases are much like other scientific and technical data bases in their structure, but historically have been much different in terms of their access.

3. Despite some user aggravation in certain types of searches, the structure of data bases seems tailored to user needs. Ongoing refinements and the development of new types of data bases should even more carefully tailor data bases to user needs.

4. The data base industry has a few large publishers of many data bases, and many small publishers. This observation carries with it as yet unanswered questions.

5. In terms of the activities of data base publishers, NASA seems well specialized in its provision of

technical staff for analytical and consultative purposes.

6. With increasing dial-up access to RECON/NASA, there may be reason for re-evaluating the role of the IAC's. If this is done, it is important to emphasize their current specialization in analytical and consultative services.

Appendix A

CONTENTS

Source: Information Market Place: 1978-79

Appendix B

Subject area headings from _Information Market Place_, 1978-1979 used to select data bases of direct relevance to a private sector scientist or technologist:

Aerospace and Aeronautical Engineering
Agriculture and Agricultural Engineering
Astronomy
Biology
Chemistry and Chemical Engineering
Civil Engineering
Computers, Data Processing Systems
Current Research Projects
Earth and Space
Electronics and Electrical Engineering
Energy
Engineering
Environment
Food Science
General Science and Technology
Geology
Life Sciences
Mathematics
Mechanical Engineering
Medicine
Metallurgy
Nuclear Science
Patents
Petroleum
Physics
Pollution
Technology

Appendix C

The data bases selected for the sample studied in this report, and their publishers, are:

DATA BASE NAME	DATA BASE PUBLISHER
1. API Tech Index	American Petroleum Institute--CAIS
2. ASTM Infrared Data Base	Sadtler Research Laboratories, Inc.
3. Agricola	National Agricultural Library
4. Biosis Previews	BioSciences Information Service (BIOSIS)
5. CA Condensates (CA Con)	Chemical Abstracts Service
6. CA Subject Index	Chemical Abstracts Service
7. Cancerproj	International Cancer Research Data Bank: Smithsonian Science Information Exchange
8. Chemical Abstracts Service Source Index	Chemical Abstracts Service
9. Chemical Industry News (CIN)	Chemical Abstracts Service
10. Clinprot	International Cancer Research Data Bank Program (ICRDG)

11. Computer and Information Systems Abstracts; Electronics and Communications Abstracts	Cambridge Scientific Abstracts, Inc.
12. Conference Papers Index	(CPI)
13. Defense Market Measures System	Frost and Sullivan, Inc.
14. Discontinued Diode	Cordura Publications, Inc.
15. Discontinued Thyristor	Cordura Publications, Inc.
16. Drug Product Information File	American Society of Hospital Pharmacists
17. Elastomers	Cordura Publications, Inc.
18. Energy Conservation	Energy and Environmental Response Center
19. EnergyLine	Environment Information Center (EIC), Inc.
20. Environmental Impacts	Energy and Environment Response Center
21. Food and Agricultural Chemistry	Chemical Abstracts Service
22. Geological Reference File (GeoRef)	American Geological Institute
23. Hydrological Information Storage and Retrieval System (HISARS)	Biological and Agricultural Engineering
24. IRIS Infrared Information System	Sadtler Research Laboratories, Inc.

25. Interface Integrated Circuits	Cordura Publications, Inc.
26. Linear Integrated Circuits	Cordura Publications, Inc.
27. Maritime Research Information Service	MRIS
28. Medical Subject Headings (MeSH) Vocabulary File	National Library of Medicine
29. Microwave Tubes	Cordura Publications, Inc.
30. NASA RECON	NASA IAC/Knowledge Availability Center
31. Optoelectronics	Cordura Publications, Inc.
32. Pharmaceutical News Index (PNI)	Data Courier, Inc.
33. Polymer Science and Technology	Chemical Abstracts Service
34. Production Standards Format	Petroleum Information Corporation
35. Requests for Comments (RFC's)	ARPANET Netword Information Center
36. Science Citation Index (SCI)	Institute for Scientific Information
37. Small Business Data File	International Data Corporation
38. TTD Keyterm Index	Institute of Textile Technology
39. Total Marketing Analysis Research Service	DMS Inc.
40. Transdex	Bell and Howell Micro Photo Division

41. Well History Control System (WHCS)	Petroleum Information Corporation
42. World Energy Supplies System (Worldenergy)	United Nations Statistical Office

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Appendix D

DIALOG DATABASES - NUMERICAL LISTING

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? ?FILES
Accessible files:
  1* ERIC 66-79/SEPT
  2  CA SEARCH 67-71
  3  CA SEARCH 72-76
  4  CA SEARCH 77-79/VOL 91(16)
  5  BIOSIS PREVIEWS 74-79/OCT
  6  NTIS 64-79/ISS21
  7  SOCIAL SCISEARCH 72-79/WK36
  8  COMPENDEX 70-79/SEP
  9  AIM/ARM 67-76
 10  AGRICOLA 79/JUL
 11  PSYCH ABS 67-79/SEP
 12  INSPEC 69-77
 13  INSPEC 78-79/ISS18
 14  ISMEC-MECH ENGR 73-79/OCT
 15  ABI/INFORM 71-79/SEP
 16  PROMT 72-79/OCT
 17  PTS PREDALERT OCT 29
 18  F & S INDEXES 76-79/OCT
 19  CHEM IND NOTES 76-79/ISS46
 20  FEDERAL INDEX 76-79/AUG
 21  (*offline*)
 22  EIS PLANTS MAY79 (TYPES $0.50 EACH)
 23  CLAIMS/CHEM 1950-1970
 24  CLAIMS/U.S. PAT 1971-1977
 25  CLAIMS/U.S.PAT ABS 78-79/AUG: SEE FILES 23,24,125
 26  FOUNDATION DIRECTORY 1979 ED.
 27  FOUNDATION GRANTS 73-79/APR
 28  OCEANIC ABS 64-79
 29  MET/GEOASTRO ABS 70-79/FEB
 30  (*offline*)
 31  CHEMNAME(TM) FILE
 32  METADEX 66-79/JUN
 33  WORLD ALUMINUM ABS 68-79/JUL
 34  SCISEARCH 78-79/WK36
 35  COMP DISSERT ABS 1861-1979/SEP
 36  LANGUAGE ABS 73-78/ISS06
 37  SOCIOLOGICAL ABS 63-79/ISS01
 38  AMERICA: HIST & LIFE 63-78/ISS03
 39  HISTORICAL ABS 73-78/ISS03
 40  ENVIROLINE 71-79/AUG
 41  POLLUTION ABS 70-79/JUL
 42  PHARM NEWS INDEX 74-79/SEPT
 43  CA PATENT CONCORDANCE 72-78
 44  AQUATIC SCI ABS 78-79/APR
 45  APTIC 66-78/OCT
 46  NICEM 1977 ED.
 47  MAGAZINE INDEX 77-79/OCT
 48  PIRA 75-79/SEPT
 49  PAIS INTERNATIONAL 76-79/JUL
 50  CAB ABS 72-79/JUL
 51  FSTA 69-79/AUG
 52  (*offline*)
 53  (*offline*)
 54  ECER/EXCEP CHILD 66-79/MAY
 55  BIOSIS PREVIEWS 69-73
 56  ART MODERN 74-78
 57  PHILOSOPHER 'S INDEX 40-79/MAY
 58  GEOARCHIVE 74-79/MAR
 59  FROST & SULLIVAN DM2 75-78/ISS03
 60  USDA/CRIS 75-79/JUN
 61  LISA 69-79/FEB
 62  SPIN 75-79/AUG
 63  MRIS ABSTRACTS 70-79/JUNE
 64  CHILD ABUSE AND NEGLECT SEPTEMBER 1979 ED.
 65  SSIE CURRENT RESEARCH 78-79/JUL
 66  GPO MONTHLY CATALOG JUL76-79/SEPT
 67  WORLD TEXTILES 70-79/JUL
 68  EPB 74-79/JUL
 69  ENERGYLINE 71-79/SEP
 70  NICSEM/NIMIS 1978 ED.
 71  MLA Intl. Bibliography 76-77
 72  EXCERPTA MEDICA 75-79/ISS31
 73  EXCERPTA MEDICA IN-PROCESS 79/ISS39
 74  IPA 70-79/JUN
 75  MGMT CONTENTS 74-79/SEP
 76  (*offline*)
 77  CONFERENCE PAPERS INDEX 73-79/AUG
 78  NATIONAL FOUNDATIONS 1979 ED.
 79  FOODS ADLIBRA 74-79/SEPT
 80  (*offline*)
 81  PTS US STAT ABS 71-79
 82  PTS US ANL TIME SERIES JUN79
 83  (*offline*)
 84  (*offline*)
 85  (*offline*)
 86  PTS INTL STAT ABS 71-79/AUG
 87  PTS FRN ANL TIME SERIES SEP79
 88  (*offline*)
 89  (*offline*)
 90  ECONOMIC ABSTRACTS INTL 73-79/SEPT
 91  (*offline*)
 92  EIS NONMANUFACTURING MAY79 (TYPES $0.50 EACH)
 93  U.S. Political Science Documents 75-77
 94  SCISEARCH 74-77
 95  RAPRA ABSTRACTS 72-79/SEP
 96  (*offline*)
 97  RILM 8/20/79
 98  F & S INDEXES 72-75
 99  WELDASEARCH 1976-79/JUN
100  DISCLOSURE 79-79/WK43
101  (*offline*)
102  (*offline*)
103  (*offline*)
104  (*offline*)
105  FOREIGN TRADERS INDEX 79/OCT
106  TRADE OPPORTUNITIES/77-7908
107  TRADE OPPORTUNITIES/791030
110  AGRICOLA 70-78/DEC
111  NATIONAL NEWSPAPER INDEX 79-79/OCT
112  Aquaculture 79
113  (*offline*)
114  ENCYCLOPEDIA OF ASSOCIATIONS ED. 13
124  CLAIMS/CLASS JUNE 1979 ED.
125  CLAIMS/U.S. PATS.ABS. WEEKLY 10/02/79
200  DIALOG PUBLICATIONS 79/SEP
201  ONTAP ERIC
204  ONTAP CA SEARCH 15,705 DOCUMENTS
211  (*offline*)
231  ONTAP CHEMNAME(TM) 26,696 SUBSTANCES
911  NEWSEARCH
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*Trademark Reg. U.S. Pat. & Trademark Office.

Source: Guide to Dialog Searching, Lockheed Corporation

Appendix E

The publishers of the sample data bases, listed alphabetically:

1. American Geological Institute
2. American Petroleum Institute
3. American Society of Hospital Pharmacists
4. ARPANET Network Information Center
5. Bell and Howell Micro Photo Division
6. Biological and Agricultural Engineering
7. Biosciences Information Service (BIOSIS)
8. Cambridge Scientific Abstracts, Inc.
9. Chemical Abstracts Service
10. Cordura Publications, Inc.
11. DMS, Inc.
12. Data Courier Inc.
13. Energy and Environment Response Center
14. Energy Information Center
15. Frost and Sullivan Inc.
16. Institute for Scientific Information
17. Institute of Textile Technology
18. International Cancer Research Data Bank Program
19. International Data Corporation
20. Maritime Research Information Service

21. NASA IAC/Knowledge Availability Center
22. National Agricultural Library
23. National Library of Medicine
24. Petroleum Information Corporation
25. Sadtler Research Laboratories Inc.
26. United Nations Statistical Office

Appendix F

A Theoretical Discussion of the Data Base Industry Structure

An attempt was made to perform some theoretical analysis of the data base industry structure. This analysis was inspired by the works of Baumol, Fischer, and Braunstein, who have investigated cost and revenue functions from the perspective of firms producing heterogeneous goods. This perspective emphasizes a multi-dimensional analysis of the revenue and production costs of every combination of produced goods, by looking at revenue and cost behavior along and between many "output rays" in "production space." The key point is that the production of certain combinations of industrial goods may be characterized by complementarities of production and/or complementarities in consumption. If there are such complementarities, then the industry's production costs will decrease and/or the revenues will increase, respectively, with multi-good production. Thus, the industry will find it more profitable to produce particular combinations of several kinds of goods. Conversely, if a combination of goods is subject to

substitution in production and/or consumption, then the industry will be characterized by firms each producing a specialized and unique product.

If it is possible to demonstrate that there are complementarities or substitutions in production and/or consumption of certain goods (here--types of data bases), then one could demonstrate that there may be "natural" limits and "ranges of production" for firms in an industry. This would be counter to historical Economic wisdom, which has often labelled an industry with a few large producers and many small ones as "oligopolistic" and hence inefficient. Does the publishing activity of the sample publishers indicate a data base industry oligopoly, or a reflection of natural consumption and production forces?

This author, much to his regret, has no well-formulated answer to the above question.

There is great appeal in hypotheses focusing on the consumption side, and how this could largely determine a firm's size of production. Chemical Abstract's data bases most likely address much different user needs than do Cordura's or Sadtler Research Labs'. The six Chemical Abstracts data bases in the sample are bibliographic, whereas Cordura's seven and Sadtler's two are all non-bibliographic. The temptation is to assume that Chemical Abstracts data bases address users who would have

"complementarities" in consumption. This would indicate that Chemical Abstracts should produce more data bases and types of data bases than the other two. This distinction, however, does little to illustrate why both Chemical Abstracts and Cordura are "large" (14 and 26 data bases, respectively), and Sadtler is "small" (3 data bases). A proper evaluation of this issue would involve investigating all data bases produced by each of the twenty-six publishers. However, on the basis of the data bases included in the sample, and at this level of analysis, this does not appear a fruitful avenue of further research.

Looking to the production side for possible complementarity or subsitution of production, there are some a priori reasons to expect either substitutions or complementarities in the production of many types of data bases. The least controversial reason to expect complementarity in production is that producing a data base involves extensive organization and the writing of general software--each of which is a major front-end investment. Once made, these investments can be applied to the production of other data bases. Furthermore, if a firm owns its own computing facilities, then it is usually in the company's interest to spread the high fixed costs of this equipment over as much work as possible. Validating this would require examining the production processes and facilities of each data base publisher.

On the other hand, it could be possible that producing certain types of data bases involves exceptionally high production costs for a very specialized product, thus creating the potential for substitutions in production. For example, suppose there are extremely high fixed costs in developing data files and software to store and access chemical information by molecular formula. This could be an example where it is economic for a firm to produce only one or a few data bases, since the technology involved in these data bases may not easily be applied to other data bases. Yet, such data file and software technology would probably find success in separate data bases covering topics such as physical chemistry, organic chemistry, biochemistry, general medicine, pharmacology, toxicology, materials science, etc. Perhaps a better example would be to determine if Sadtler Research Labs has such a specialized expertise, and such specialized technological needs for its infrared spectral information data bases, that there would be diseconomies for Sadtler to produce other types of data bases.

An empirical study of cost functions would be of use in investigating this question.

There is an empirical study of the journal publishing industry which is interesting to cite in relation to this discussion. Baumol and Braunstein have performed an empirical study of scale economies and production

complementarities for a sample of nonprofit publishers of scientific journals.[11] Baumol and Fischer estimated a variety of cost functions, and found that about two/thirds of the firms were close to their "minimum cost locus," so that neither merging nor splitting these firms would reduce their costs. Furthermore, up to the "minimum cost locus," or "point of minimum ray average cost," costs per journal declined with the number of journals per publisher. The remaining one/third of the publishers was said to be in the region of "sub-additivity," such that limited amalgamation might reduce the firm's cost. As the journal publishing industry is more established than the relatively new machine readable data base industry, it would be interesting to see how close machine readable data base publishers are to the points of "minimum ray average cost."

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[11] Baumol, W. and Braunstein, Y.: "Empirical Study of Scale Economies and Production Complementarity: The Case of Journal Publication," Journal of Political Economy Volume 85, number 5; October 1977; pages 1037-1048

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AN INVESTIGATION OF THE LAG BETWEEN THE START OF RESEARCH AND THE DEVELOPMENT OF NEW TECHNOLOGY

Steven E. Glass
February 1982

Abstract

This paper is concerned with the lag which occurs between the start of NASA-sponsored research and the development of new technology. It is obvious that some lag exists. Technology does not spontaneously result the moment research commences. The crucial question here is, is there a common gestation period for all NASA technology?

Social scientists studying the output of privately financed research and development have assumed the existence of such a common gestation period or lag. For example, F. M. Scherer's recent work "The Propensity to Patent" tries to correlate R&D expenditures with patent output in various industries. Scherer compares R&D expenditures made in 1974 to the patents issued between June 1976 and March 1977 obtaining a 9 to 30 month period between research and patent application.

This work attempts to measure the lag by correlating measures of R&D efforts with measures of technological output. Such output measures are only as good as the data on which they are based, so data problems are discussed in some detail.

The lags found by the procedure described in this report vary from zero to one year, significantly shorter than Scherer's findings. A possible explanation for this difference is that research on government R&D projects commences before the indicators of research effort show a change.

AN INVESTIGATION OF THE LAG BETWEEN THE START OF RESEARCH AND THE DEVELOPMENT OF NEW TECHNOLOGY

By

Steven E. Glass

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1. INTRODUCTION

This paper is concerned with the lag which occurs between the start of NASA-sponsored research and the development of new technology. It is obvious that some lag exists. Technology does not spontaneously result the moment research commences. The crucial question here is, is there a common[1] gestation period for all NASA technology?

Social scientists studying the output of privately financed research and development have assumed the existance of such a common gestation period or lag. For example F. M. Scherer's recent work "The Propensity to Patent"[2] tries to correlate R & D expenditures with patent output in various industries. Scherer compares R & D expenditures made in 1974 to the patents issued between June 1976 and March 1977. This implies a lag of 18 to 39 months between research expenditures and the patenting of new technology. If we subtract the average nine months it takes to obtain a patent,[3] we obtain a 9 to 30 month period between research and patent application.

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[1] The word "common" was chosen deliberately. An alternative is "average", but an average can always be calculated from observations of lag times. "Common" implies the variance in lag times for different technologies is small.

[2] Presented at the 1980 Allied Science Association Meeting at Denver Colorado, September 5, 1980.

[3] This was reported by C. A. Agnew et. al., "A Study of Some of the Effects of Public R&D on the Private Sector," Princeton, N.J.: Mathtech Inc., October 30, 1979.

This work attempts to measure the lag by correlating measures of R & D effort with measures of technological output. Such output measures are only as good as the data on which they are based; data problems are discussed in some detail below.

The following model will be the focus of our thinking on the relationship between research and the development of new technology.

$$T(k) = f(R(k-m),R(k-m+1),\ldots,R(k-1),R(k)) \qquad (1)$$

where T(k) is the technology developed in year k

R(i) is the research effort made in year i

m is the number of years after which research effort does not affect technological output

Equation 1 suggests that the technology developed in time period k, T(k), is a function of the research effort, R(.), made in time period K and in previous time periods k-1, k-2, ... , k-L. The function f(.) generally can take on any form. For this exercise however, only linear models will be considered. The relationship as written also suggests that the functional relationship remains constant through time.
This is what the linear model proposes:

$$T(k) = a + c_m R(k-m) + \ldots + c_o R(k) \qquad (2)$$

A nonlinear model is more complex than this. However, it allows additional units of research effort to have different marginal effects. Economies of scale therefore can be modeled such that additional research efforts result in more than proportional increases in technological output. Scherer tests for nonlinearities in his work[4] and finds that statistically significant nonlinearities existed in some industries and not in others. The significant nonlinearities were both positive and negative indicating both economies and diseconomies of scale.

Scherer's finding of statisically significant departures from the linear model benefited from an extremely large sample size. There are not enough data points available for this study to attempt to draw equally strong conclusions. For example, in a quadratic model, ignoring interaction effects (i.e. cross-product terms), the number of coefficients which must be estimated is one less than twice the number to be estimated for the linear equation. A linear three year lag model requires four coefficients while the quadratic three year lag model requires seven.

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[4] Scherer, op. cit.

2. MEASURING RESEARCH EFFORT AND TECHNOLOGY DEVELOPMENT

Social scientists have always found it difficult to study research and technology. Many of their problems have related to data; those wishing to make statistical inferences about research and technology are forced to utilize indirect indicators of these quantities. Results and interpretations of studies using such indicators are questioned by academics and decision makers alike.

Social scientists commonly use two different indicators of research effort:[5] R&D dollars spent and employment of scientists and engineers; they also comonly use two different indicators of technological output: invention disclosures reported and patent applications made. Each of these measures has drawbacks when used to study industrial research and development, as discussed in the following subsections.

2.1 R&D DOLLARS

Generally the amount of money spent on R&D is not consistently measured because accounting practices vary from organization to organization and through time. In the case of NASA, this is not an important consideration, unless comparisons are made between NASA and other R&D entities. However, other problems exist.

From the viewpoint of federal budgeting, NASA is an R&D agency, and almost every dollar it spends is considered R&D spending. Unfortunately,

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[5] For example, Solo's and Scherer's work already mentioned.

much of this money is not spent on research or the development of new technology. For example, the money NASA spends acquiring launch vehicles is considered R&D spending. This is the case even though the technology for making a Centaur or Delta rocket has already been developed, and paid for. The same is true for the procurement of other technologically advanced equipment (e.g. computers, tracking devices).

It is possible to look at NASA budgets and roughly separate the money spent on "true" R&D from the rest. However, exercises of this type result in expenditure estimates that tend to be proportional to the total NASA budget.[6] Hence, the resulting expenditure streams should result in statistical predictions that do not differ by more than a proportionality constant.

The work reported here therefore uses total NASA expenditure figures, rather than picking out research expenditures from the rest. Figure I gives the history of NASA outlays in constant dollars by calendar year. The figures were derived from fiscal year data by averaging, and converted to constant dollars using the GNP price deflator. (The data used for the figure are given in Appendix A. Its derivation is described in Appendix C.)

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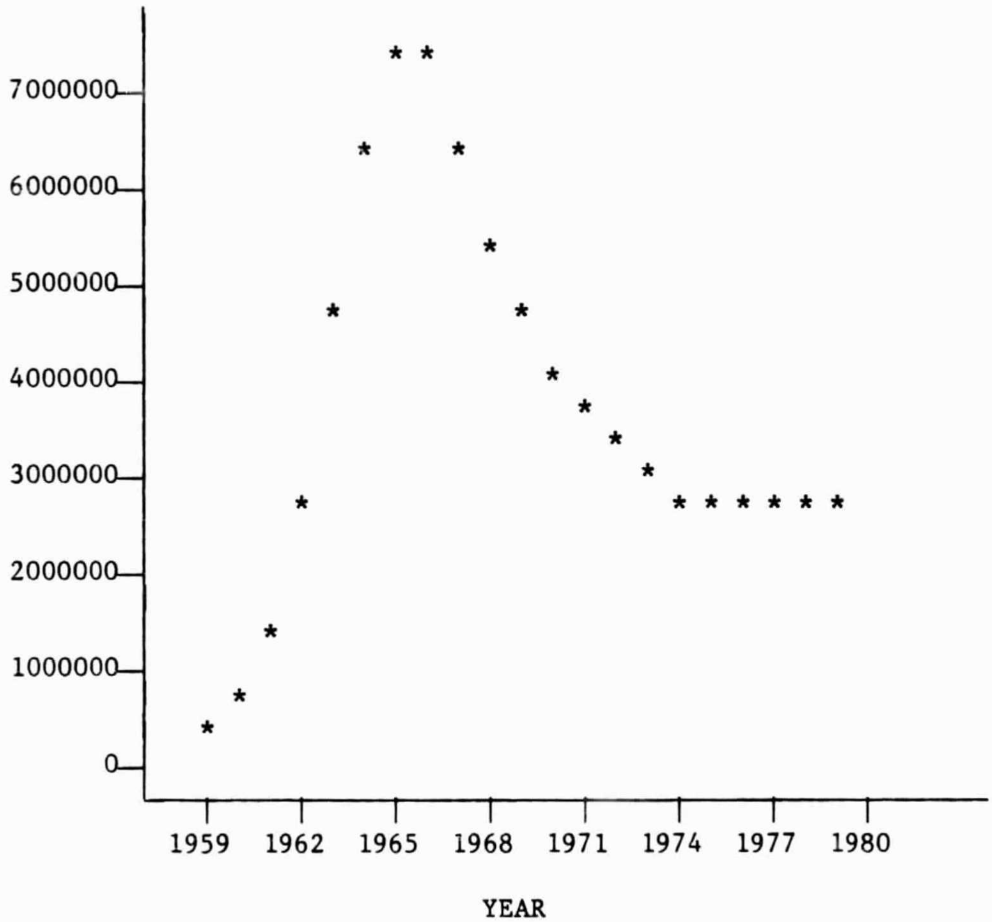
[6] Unpublished work by Henry Hertzfeld at NASA demonstrates this fact, but it is not surprising that this should be the case. The budgetary process is such that it is easier to get congressional approval for budgets that are proportional to previous budgets than to risk major changes.

Figure I

NASA R&D OUTLAYS
By Calendar Year in 1972 Dollars



2.2 NASA EMPLOYMENT

As measures of R&D effort employment statistics face criticism because employees differ in ability, desire and level of interest in their work. Moreover, individuals counted as scientists and engineers may actually be management personnel, no longer engaged in research. Records exist on the number of civil service employees working for NASA through the years,

showing what type of worker they were. However, since NASA contracts with private firms for most of its research, these numbers do not give a complete picture. Some records are kept on the number of people employed by contractors. Unfortunately, these are kept for only a small percentage of contracts. NASA estimates the employment generated by other contracts from budget expenditures using a multiplier and price deflator. The resulting employment figures are definitely not independent of expenditure records.

Even though employment records do not exist for the entire NASA program, the in-house employment records are valuable because the number of NASA employees classified as scientists and engineers provide an indirect measure of NASA's internal research and development effort. However, this figure still has the drawbacks that some scientists and engineers perform management tasks or oversee contract research, and do not perform research themselves. Still, the internal figures are probably a better indicator of NASA's internal research effort than the totals, and are used here for that purpose.

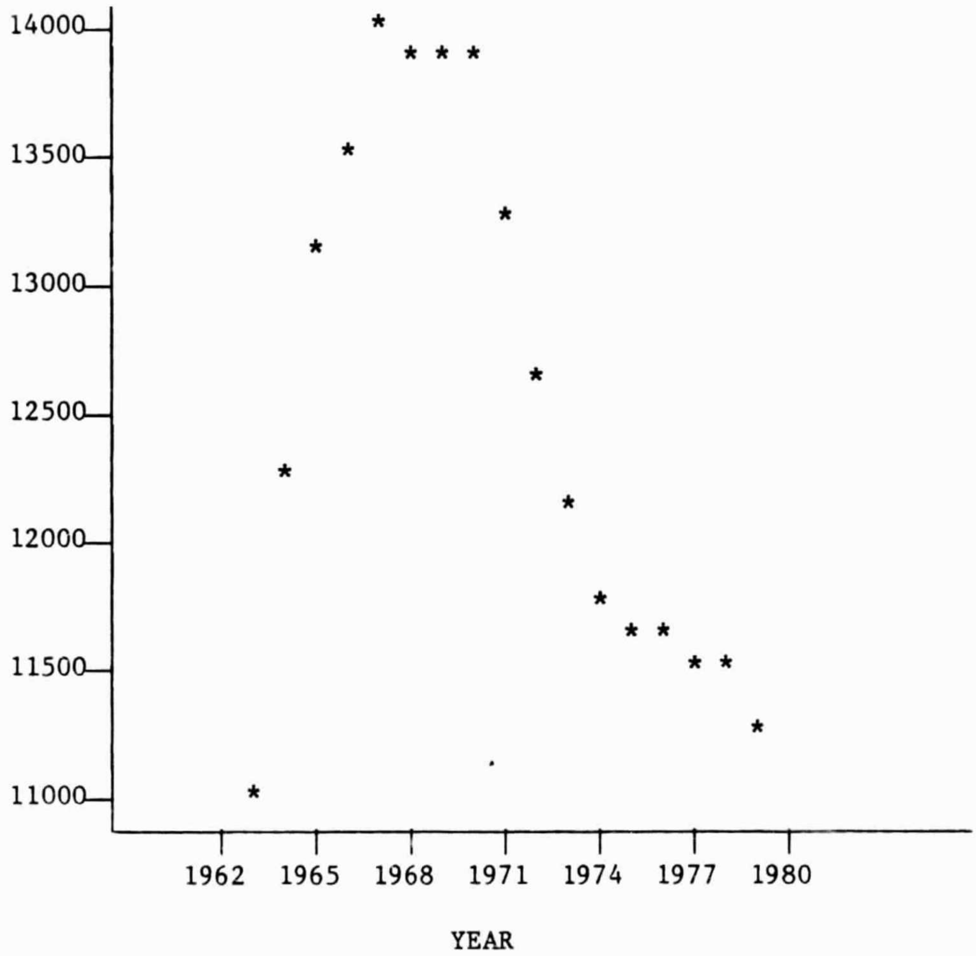
The employment history is given in Figure II. (The data are given in Appendix A. Its source is described in Appendix C.)

2.3 INVENTION DISCLOSURES

NASA employees and contractors are required to disclose potentially significant inventions to NASA. A general problem with invention disclosure reporting, however, is that individual technologists are subject to the varying rules of their particular organization. In addition, there is the inherent desire of private organizations to keep inventions secret.

Figure II

NASA EMPLOYMENT OF SCIENTISTS AND ENGINEERS



Both NASA employees and contractors are required to report newly developed technology to NASA authorities. The reports are made to the NASA field center responsible for the work and coordinated by a technology utilization (TU) officer. The TU officer assigns a case number to the invention and starts a screening process which leads to decisions on whether or not a patent application should be made and whether or not the new invention should be announced in the NASA's Tech Brief Journal. All inventions which enter the screening process are counted as invention disclosures.

Invention disclosures thus have a problem, shared with patent data, when used as indicators of new technology: the disclosures are for inventions of differing quality. It might be more accurate to use only inventions which successfully pass through the screening process; for such inventions, either a patent application is made or an anouncement is made in the Tech Brief Journal. Unfortunately data on such inventions are not readily available.

Difficulty in identifying which inventions are to be reported also leads to problems with the disclosure series used here. Companies working for NASA are required by their contracts to report any new technology developed. Contractors and contract managers have guidelines for reporting of new technology. The guidelines were printed in handbooks and published in 1966 and 1969.[7] The rules for reporting have not changed since then but the NASA effort put into enforcing the rules has not necessarily been constant. If the effort has remained constant then the invention disclosures are equivalent measures for each year since the reporting rules were published. On the other hand, if, as seems likely, NASA's enforcement effort has been flagging, then the more recent invention disclosures tend to understate the technology developed.

Even NASA employees do not operate under a clear a set of invention disclosure rules. Inventions are reported by employees and their supervisors to Technology Utilization (TU) Officers at each field center. The reporting takes place because employees are aware of the TU program and

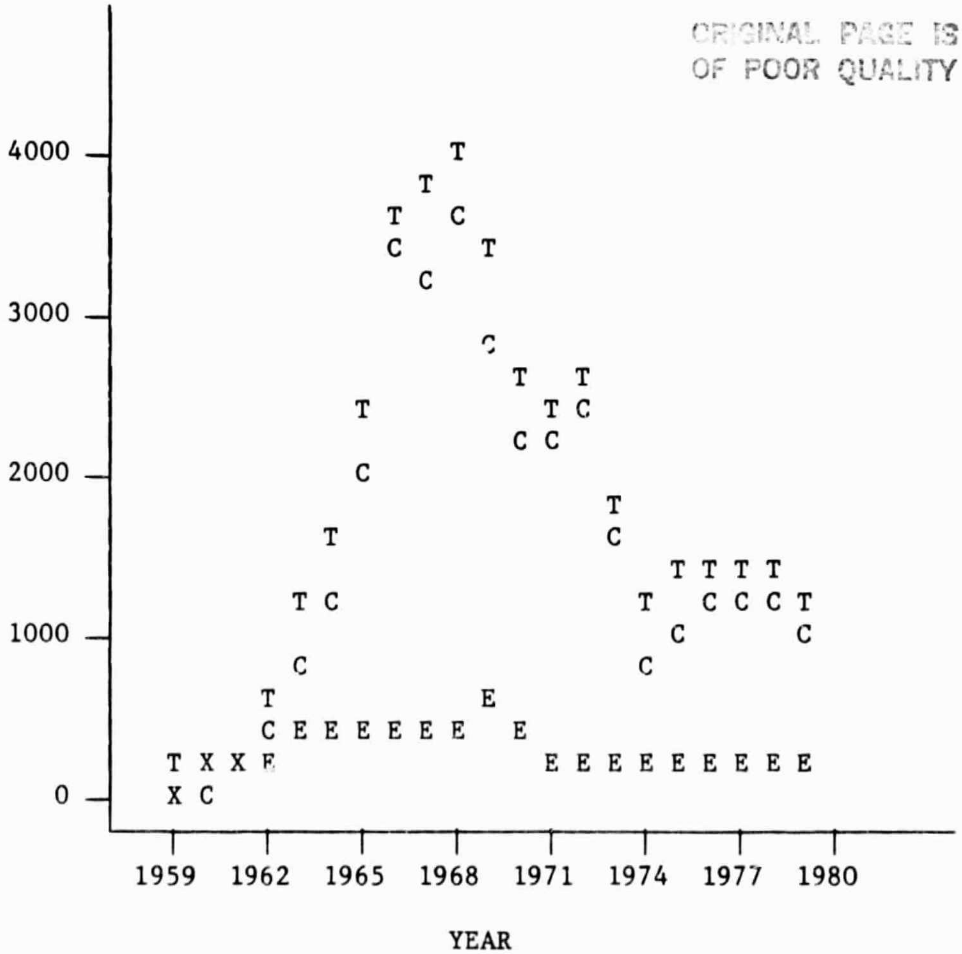
[7] These are NASA Handbook (NHB) 2170.1 and NHB 2170.3.

because of an Incentive Awards Program. The Incentive Awards Program at NASA rewards inventors based on the value of their invention (as determined by an awards committee). The relationship between this program and invention reproting is not clearly defined. It is very difficult to say how employee invention reporting has varied over time at NASA.

The invention reporting records are given in Figure III. (The associated data are given in Appendix A. Its source is described in Appendix C.)

Figure III

NASA INVENTION DISCLOSURES



Legend:

T is Total Disclosures
E is NASA Employee Disclosures
C is Contractor Disclosures

2.4 PATENT APPLICATIONS

The general problems with using patent applications as an indicator of the results of R&D include: patent policies vary from organization to organization; patents do not promote the commercialization of technology that is not patentable; and it does not always pay to patent those new technologies which are patentable.[8]

At NASA, patent applications are filed for ten to twenty percent of the inventions reported. Title to patented inventions can be obtained by NASA, the contractor or the NASA employee inventor. NASA obtains title to all patented inventions not wanted by their inventors. Final disposition of title to other inventions depends on the applicability of NASA's Patent Waiver Regulations (for contractors) and Executive Order 10096 issued by President Nixon (for employees).[9] Only a few employee patents are not owned by NASA while approximately half of the contractor patents remain with the contractor.

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[8] These problems have been discussed in detail by many of the scholars who have used these data before. Almost all discussions reference Jacob Schmookler's work. His discussions are contained in his book Invention and Economic Growth, Cambridge: Harvard University Press, 1966; and the first part The Rate and Direction of Inventive Activity, The Universities-National Bureau Committee for Economic Research and the Committee on Economic Growth of the Social Science Research Council, Princeton: Princeton University Press, 1962, pp. 19-92. Recent work by Donald A. Dunn also discusses the problems of patents as indicators of the advancements in some technologies: "Information Resources and the New Information Technologies: Implications for Public Policy", National Science Foundation report to the President and Members of Congress, The Five Year Outlook on Science and Technology, Vol II pp. 493-507, May 1980.

[9] It is not clear what happened to employee inventions before the Nixon order, but since so few employees have tried to keep their inventions, the numbers are not significant.

Other problems associated with patents as indicators of R&D output relate to the government's decision making process for patents. Private companies tend to acquire patents for commercial reasons; the government does not base its decision entirely on the commercial potential of an invention.[10] "Defensive" reasons are often mentioned to justify obtaining patents on NASA inventions without commercial potential; this includes NASA obtaining patents to prevent companies or foreign governments from acquiring exclusive rights to technology it needs for various missions. Another reason mentioned is to reward employees for work done; an employee who makes a useful but not commercially valuable invention is rewarded by having the agency obtain a patent.

Since many patenting decisions are not made solely on the basis of commercial factors, patents may not be a stable indicator of the output of newly developed technology. In fact if we look at NASA's patent history, we find that the number of patent applications made by NASA has remained relatively constant. The number has not been nearly as volatile as invention disclosures. As invention disclosures declined in the 70's, the percentage of disclosures for which patent applications were made, increased. This suggests that patents in the later years overstate the technology developed by NASA compared to the earlier patents.

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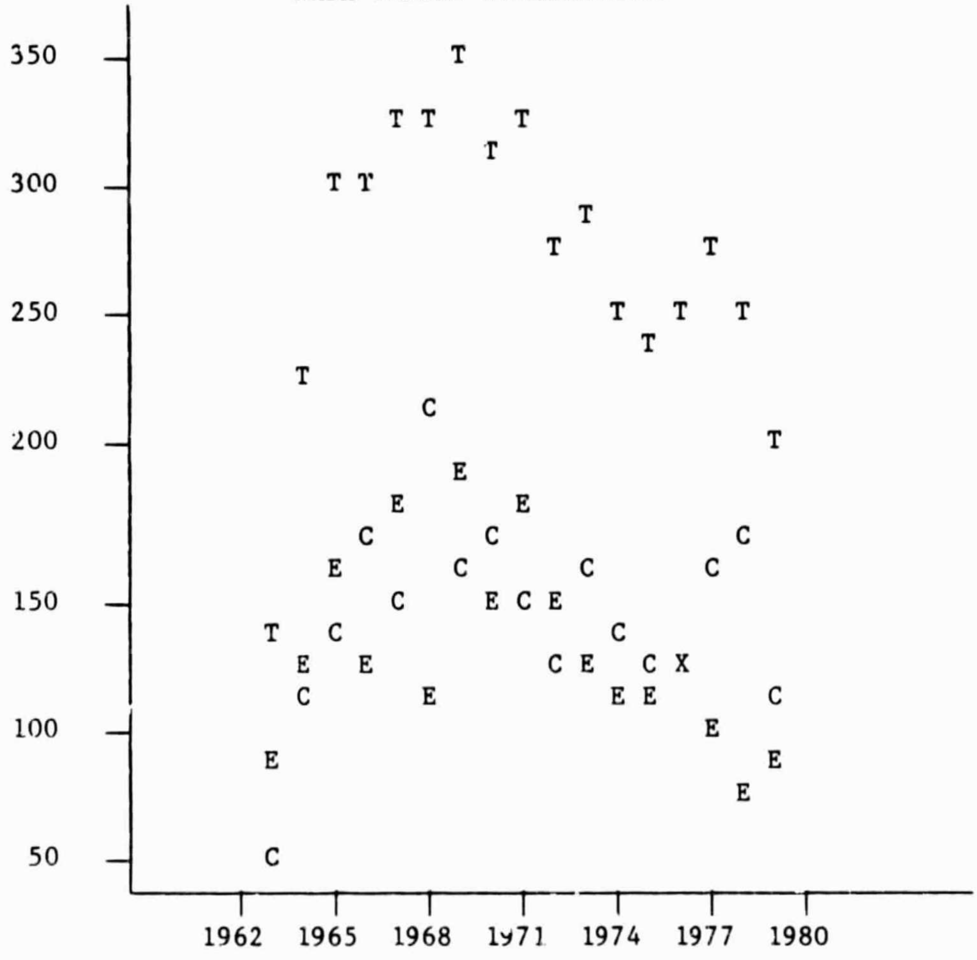
[10] This difference has been recognized for a long time. See for example Mary A. Holman, "The Utilization of Government Owned Inventions", Patent Trademark and Copyright Journal of Education and Research (IDEA), 7(2):109-?, 1963; Donald S. Watson and Mary A. Holman, "Patents From Government Financed Research and Development", Patent Trademark and Copyright Journal of Education and Research, 8(2):pp. 199 ff, 1964; and Robert A. Solo, "Patent Policy for Government Sponsored Research and Development", Patent Trademark and Copyright Journal of Education and Research, 10:143-206, 1966.

NASA's patent application history is given in Figure IV. (The data on which Figure IV is based can be found in Appendix A. Its source is described in Appendix C.)

Figure IV
NASA PATENT APPLICATIONS



Legend:

T is Total Disclosures
E is NASA Employee Disclosures
C is Contractor Disclosures

3. THE STATISTICAL TESTS

3.1 METHOD

The statistical method for determining whether a common lag exists is based on Mizon,[11] who suggests sequential testing of related hypotheses. First equation 2 is restated.

$$T(k) = c(o)\ R(k) + c(1)\ R(k-1) + \ldots + c(m)\ R(k-m) + a \qquad (2')$$

The number "m" would be a number of years after which research effort has no effect on the technology developed in year k. The sequential test hypothesizes *a priori* a value for m which is certain to be valid, and tries to find a smaller lag which is consistant with the observed data. Given the formulation of Equation 3, we test the hypotheses

$$\begin{aligned} &H(m)\colon\ c(m) = 0 \\ &H(m-1)\colon\ c(m) = c(m-\ell) = 0 \\ &H(m-2)\colon\ c(m) = c(m-1) = c(m-2) = 0 \\ &\qquad\vdots \end{aligned}$$

Each hypothesis is tested by forming an F-ratio. When the probability level of the test reaches a critical level (i.e. when F becomes large enough to reject $H(m-\ell)$ say), the procedure stops and the hypothesis accepted is that the lag is ℓ. The test proceeds backwards (from longer to shorter lags).

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[11] Grayham E. Mizon, "Inferential Proceedures in Nonlinear Models: An Application of a UK Industrial Cross Section Study of Factor Substitution and Returns to Scale", *Econometrica*, 45(5):1221-1242, 1977.

In this work, the tests are performed with an m of 5. A higher value of m would have left very few degrees of freedom. As it is, with 21 observations on research effort and technological output, data lagged five years allows only 16 cases to be used in the statistical calculations.

Although the tests described above are not necessarily independent, the critical value is chosen as if this were the case. If the overall critical value of the test is to be A the individual F tests have a critical value of A' where

$$A = 1 - (1 - A')**M$$

or approximately, A' = A/M. The goal was to obtain overall results at a 5% level. Hence in the case of M = 5, each individual test used a 1% critical value.

3.2 RESULTS.

Six sets of hypotheses were tested. The results are given in Appendix B. The Appendices tables show the F statistic for the test that the last $m-\ell$ variables are zero. (m is the maximum lag and ℓ is the hypothesized lag.) Also contained in these tables are the coefficients of the resulting models, computed two ways: with and without an intercept. (In many cases the intercept was not significantly different from zero.) The tables below summarize the results of the Appendices. It shows the lag (ℓ) obtained from each specification of dependent and independent variables.

Table of Significant Lags for m = 5

Independent Variable	Dependent Variables	Lag
Total Invention Disclosures	Total Outlays	1
Total Patent Applications	Total Outlays	1
Contractor Invention Disclosures	Total Outlays	1
Contractor Patent Applications	Total Outlays	*
Employee Invention Disclosures	Employment	0
Employee Patent Applications	Employment	*

* No relationship was significant.

4. CONCLUSIONS

The lags found by this procedure vary from one to zero years. This is shorter than Scherer's asumption of 9 to 30 months.[12] A possible explanation for this difference is that research on government R&D projects commences before the indicators of research effort show a change. For example, when the government contracts with a company to do research, the company may have done some work prior to the execution of the contract. Further expenditures will be recorded by NASA only after they are billed for work executed by the contractor. Also important is that a large payment may even come at the end as with many incentive award contracts.

Thus, the time between when the money is spent and an invention is disclosed or patent application is made may be shorter than the time between when the contractor does the work and prepares a disclosure or patent application. These factors suggest the the shorter lags discovered here are not unreasonable.

The lags between employment and technological output appear to be shorter than the lags between total outlays and technological output. A possible explanation for this result is that employment figures are even slower to indicate changes in research effort than spending changes. This is not too surprising since government agencies are slow to reduce their size as the work they do is cut back.

A potentially surprising conclusion is that the observed lag as it relates to patent applications is shorter than the lag as it relates to

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[12] Scherer, op. cit.

invention disclosures. One would think that on the basis of government reporting regulations and patent law, the patent application lag should be greater than or equal to the invention disclosure lag. Government regulations specify clearly that invention disclosures are to be made promptly upon reduction to practice of the invention. The decision to patent generally involves an assessment of commercial risk against known patenting costs, and a patent application involves months of preparation. Thus, it would be surprising to find a patent application being filed even simultaneously with a disclosure for the same invention, were the world to obey government regulations perfectly.

Furthermore, even if a disclosure to a government agency were to constitute a public disclosure (which it may or may not), the firm is still granted a one year grace period to obtain U.S. patent rights. Thus, if a firm is only interested in U.S. patent protection, patent law removes the incentive to patent first and disclose later.

The explanation for this unexpected result lies perhaps in the history of judicial reaction to patent infringement cases, and in the resultant forms of protection adopted by firms. Supreme Court and lower court hostility to patent protection, in addition to the cost and lengthy process of filing and protecting a patent, has led many firms to adopt "trade secret" protection. "Trade secret" protection has been upheld under state law, and has been adopted particularly among industries featuring rapidly evolving technology. In these industries a particular invention could become obsolete even prior to the issuance of the patent, so that the incentive to patent is entirely removed.

Since NASA hires contractors to perform research and development work on advanced technology, it is likely that NASA contractors will find trade secret protection advantageous. Even if their technology does not risk obsolescence in the immediate future, the firm might evaluate the costs and risks of patenting and protecting the patent as being in excess of the gains derived from obtaining that patent. Trade secret protection would in either case be preferred, and it would be to the firm's benefit to delay disclosure as long as possible.

The lag between contract funding and either invention disclosure or patent application is thus seen to be a function of individual perceptions on the appropriate method of protecting particular intellectual property, and of corporate policy. This insight may best explain the unusual results concerning disclosure and patent lags. For those inventions that are perceived best protected by patents, an application is filed early. For those on which a patent is not seen advantageous, no disclosure action is taken until the latest possible time. Note that this last result can also occur because of a human reluctance to engage in auxiliary paperwork, leading to procrastination in reporting activities such as invention disclosures.

A final conclusion relates to indicators of technological output. The sequential hypothesis testing showed that invention disclosures correlated better to the measures of research effort used than did patent applications. This suggests that invention disclosures are a better indicator of technological output than patent applications. This is not surprising since the decision to make a patent application is more complex

than the decision to make an invention disclosure. NASA's attitude regarding patent applications has not been as consistant as its attitude regarding invention disclosures. Moreover, most congressional interest and policy direction has related to patenting rather than the disclosure of information.

APPENDIX A

DATA FROM FIGURES IN THE TEXT

YEAR	R&D OUTLAYS	EMPLOY OF S & E	INVENTION DISCLOSURES		PATENT APPLICATIONS			
					NASA OWNED		EMPL OWND	CNTR OWND
			NASA	CNTR	EMPL	CNTR		
1959	4030[illegible]4		92	17				
1960	831132		123	71				
1961	1439784		131	162				
1962	2701702		212	449				
1963	4701678	10965	435	759	71	32	15	23
1964	6362569	12249	412	1203	114	83	9	25
1965	7429852	13115	382	2094	149	91	9	45
1966	7404628	13556	367	3310	112	112	10	60
1967	6423671	13956	487	3268	164	91	11	57
1968	5439636	13851	434	3551	106	163	10	48
1969	4621709	13839	535	2827	184	118	4	43
1970	3911732	13837	415	2145	142	113	4	57
1971	3547862	13227	265	2145	165	85	12	66
1972	3387050	12616	265	2304	144	72	9	55
1973	3116698	12085	279	1608	118	111	8	46
1974	2809087	11770	251	878	108	84	9	48
1975	2724077	11665	260	1091	105	72	8	49
1976	2815187	11629	260	1152	110	93	12	31
1977	2791196	11544	260	1200	101	112	4	54
1978	2654686	11[illegible]65	252	1123	75	140	2	38
1979	2659570	11234	221	1052	89	73	2	42

Appendix B
Hypothesis Testing with m = 5

Total Invention Disclosures by Total Outlays
(With Intercept)

Hypothesis Years Tested	F-Statistic	Degrees of Freedom		Prob < F
5	2.5137	1	9	0.1473
4,5	1.6412	2	9	0.2468
3,4,5	1.5332	3	9	0.2718
2,3,4,5	2.9484	4	9	0.0820
1,2,3,4,5	22.5616	5	9	0.0001

Parameter	Estimate	Standard Error
Intercept	203.262	169.170
0	- 3.495 E -4	9.505 E -5
1	8.177 E -4	8.842 E -5

(No Intercept)

Parameter	Estimate	Standard Error
0	- 3.051 E -4	8.865 E -5
1	8.161 E -4	8.949 E -5

Patent Applications by Total Outlays
(With Intercept)

Hypothesis Years Tested	F-Statistic	Degrees of Freedom		Prob < F
5	0.0735	1	9	0.7924
5,4	2.2586	2	9	0.1604
3,4,5	3.0752	3	9	0.0833
2,3,4,5	4.0751	4	9	0.0372
1,2,3,4,5	10.3186	5	9	0.0016

Parameter	Estimate	Standard Error
Intercept	209.330	18.892
0	- 3.855 E -5	8.41 E -6
1	5.319 E -5	8.42 E -6

(No Intercept)

Parameter	Estimate	Standard Error
0	- 1.751 E -5	2.473 E -5
1	7.493 E -5	2.472 E -5

Contractor Disclosures by Total Outlays
(With Intercept)

Hypothesis Years Tested	F-Statistic	Degrees of Freedom		Prob < F
5	4.1834	1	9	0.0711
4,5	2.2531	2	9	0.1609
3,4,5	1.6947	3	9	0.2371
2,3,4,5	2.4541	4	9	0.1212
1,2,3,4,5	18.0903	5	9	0.0002

Parameter	Estimate	Standard Error
Intercept	77.732	160.991
0	- 3.690 E -5	9.046 E -5
1	7.884 E -4	8.414 E -5

(No Intercept)

Parameter	Estimate	Standard Error
0	- 3.520 E -4	8.155 E -5
1	7.875 E -4	8.232 E -5

Contractor Patent Applications by Total Outlays (With Intercept)

Hypothesis Years Tested	F-Statistic	Degrees of Freedom		Prob < F
5	0.0826	1	9	0.7803
4,5	0.0671	2	9	0.9356
3,4,5	0.0504	3	9	0.9841
2,3,4,5	0.0381	4	9	0.9967
1,2,3,4,5	1.4238	5	9	0.3035
0,1,2,3,4,5	1.25	6	9	0.3676

Coefficients For A 1 Year Lag With Intercept

Parameter	Estimate	Standard Error
Intercept	119.034	15.539
0	- 2.840 E -5	6.914 E -6
1	3.399 E -5	6.924 E -6

Employee Invention Disclosures by Employment
(With Intercept)

Hypothesis Years Tested	F-Statistic	Degrees of Freedom		Prob < F
5	2.0602	1	9	0.2107
4,5	1.4389	2	9	0.3209
3,4,5	1.9889	3	9	0.2342
2,3,4,5	2.5550	4	9	0.1657
1,2,3,4,5	5.9982	5	9	0.0357
0,1,2,3,4,5	19.8761	6	9	0.0024

Parameter	Estimate	Standard Error
Intercept	- 419.378	231.598
0	6.070 E -2	1.845 E -2

(No Intercept)

Parameter	Estimate	Standard Error
0	0.0274	1.599 E -3

Employee Patent Applications by Employment
(With Intercept)

Hypothesis Years Tested	F-Statistic	Degrees of Freedom		Prob < F
5	0.0523	1	9	0.8281
4,5	3.5463	2	9	0.1099
3,4,5	2.1060	3	9	0.1833
2,3,4,5	2.4460	4	9	0.1766
1,2,3,4,5	2.8015	5	9	0.1413
0,1,2,3,4,5	6.0781	6	9	0.0332

Parameter	Estimate	Standard Error
Intercept	- 168.758	64.200
0	2.381 E -2	5.112 E -3

(No Intercept)

Parameter	Estimate	Standard Error
0	0.01041	4.855 E -4

Coefficients For A 1 Year Lag
With Intercept

Parameter	Estimate	Standard Error
Intercept	- 168.090	75.228
0	1.697 E -2	1.200 E -2
1	6.828 E -3	1.164 E -2

Appendix C

Data Sources

The expenditure data originated from the yearly fiscal data reported in the NASA Pocket Statistics of 1980. For the years before the transition quarter, the value for calendar year X was computed as the average of fiscal year X and X + 1. After the transition quarter, calendar year X was computed as three-fourths of fiscal year X and one-fourth of fiscal year X + 1. For the transition year, the amount was one-half of the fiscal year plus the transition amount plus one-fourth of the next year's amount. The resulting calendar year numbers were then discounted using the GNP price deflator.

The employment data were obtained from NASA's personnel office. They are the number of employees classified as scientists and engineers employed at the end of each fiscal year.

The invention disclosure and patent application information came from the yearly summary of NAsA patent activities put out by the General Counsel for Patent Matters. The summary for 1980 was in an undated memo of general distribution circulated in mid-1981.

ORGANIZATIONAL OPTIONS FOR THE TRANSFER OF SPACE TECHNOLOGY TO COMMERCIAL MARKETS

Donald A. Dunn
February 1979

Abstract

Technology transfer as used here refers to transfers from the U.S. space program to the commercial sectors of the economy. Over a hundred billion dollars have been invested by the U.S. in space technology R&D in the last two decades, and there will undoubtedly be a continuing flow of federal funds into this field in the years to come. Many of the technological advances that have been made in space technology have been adopted by firms producing commercial products. These "spinoffs" from the space program have strengthened U.S. industry's competitive position in world markets and have provided improved services and products to U.S. consumers.

Various information services are now provided by NASA to assist private firms in taking advantage of new developments in space technology. The issue that is addressed in this paper is, are there other approaches to technology transfer that might supplement the information service approach that NASA has taken thus far? A legislative initiative by Rep. Fuqua is reviewed that proposes an organizational form used in Japan and England: the private or quasi-governmental research and development corporation.

ORGANIZATIONAL OPTIONS FOR THE TRANSFER OF SPACE TECHNOLOGY TO COMMERCIAL MARKETS

by

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February 1979

Working Paper No. 2

PROGRAM IN INFORMATION POLICY

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Background

Technology transfer is used here to refer to transfers from the U.S. space program to the commercial sectors of the economy. Over a hundred billion dollars have been invested by the U.S. in R&D in space technology in the last two decades, and there will undoubtedly be a continuing flow of federal funds into this field in the years to come. Many of the technological advances that have been made in space technology have been adopted by firms producing commercial products. These "spinoffs" from the space program have strengthened U.S. industry's competitive position in world markets and have provided improved services and products to U.S. consumers. Some of the fields in which space technology can serve users in commercial markets are as follows.

1. Communication satellites.
2. Remote sensing satellites for earth resources, oceans, and weather information.
3. Space transportation and provision of facilities for space industrialization operations.
4. Space energy.

Various information services are now provided by NASA to assist private firms in taking advantage of new developments in space technology. The issue that is addressed in this paper is, are there other approaches to technology transfer that might supplement the information service approach that NASA has taken thus far? A recent legislative initiative by Rep. Fuqua is reviewed that proposes an organizational form that has been used in Japan and England, the private or quasi-governmental research and development corporation.

The investment in space technology has not only resulted in specific concepts and pieces of hardware that can be described in information bulletins, but also has resulted in a space industry that consists of trained people, techniques, and specialized facilities that are located in a number of U.S. firms and spaceflight centers. This industry is capable of producing new space technology for commercial markets, either by itself or jointly with other industries that are already involved in commercial markets. The concept of technology transfer that is considered here is not the transfer of an existing product concept to a commercial market, but rather the use of the knowledge base of the space industry to create new products for commercial markets. It is thus more a transfer of a capability than the transfer of information.

In order to develop new space-based products and services, it is necessary to go through a conprehensive product planning process and then the usual development process. Both processes must be carried out in close conjunction with potential users, in order to be sure the new products or services will be accepted in the commercial market. The product planning process, as envisioned here, includes at least the following steps.

1. Product conceptualization.

   What kind of market would be served and what would the general aspects of the new product be?

2. Product design.

   What specific alternatives are available and what would be the expected costs for each?

3. Market estimates.

   What would the expected revenue be for each alternative and what is the range of uncertainty in each estimate?

4. Institutional factors.

   Are there regulatory or legal obstacles to the introduction of the product to the market?

   Can these obstacles be overcome by administrative or legislative action or changes in product design?

This process is a highly creative one, in which a product design team that includes team members with a deep understanding of space technology and team members with an understanding of specific commercial markets work together to evolve a plan for a new product and its introduction to the market.

Organizational Alternatives

The issue can now be restated as follows. What are some reasonable organizational approaches to new product planning of this type? Several alternatives immediately suggest themselves.

1. Leave it to the aerospace firms.

   Leave this process to the aerospace firms that have the capability to create new space technology devices and systems. If there are profitable opportunities in commercial markets, these firms will find them and either develop new products by themselves or in cooperation with other firms.

2. Tax incentives for R&D.

   Give private sector firms an incentive to conduct R&D for commercial markets by giving R&D expenses a special tax status.

3. Government sponsored commercial R&D

   Use government funds to finance private sector development of new commerical products, just as government funds are used to finance the private sector development of new space technology for use by NASA. Product planning would be done partly by government, in establishing product specifications, and partly by industry, in developing a product to meet the specificiations.

4. Government product planning and development.

   Carry out product planning and development of new products entirely within NASA.

5. A space research and development corporation.

   Establish a private corporation that would provide funds for private sector development of new commercial products on the understanding that these funds plus a percentage of revenues or profits would be returned to the corporation from the revenues obtained by industry from successful products. Product planning would be done entirely by industry and only be subject to approval by the corporation.

Some comments on each of these alternatives follow.

1. Leave it to the aerospace firms.

   A weakness of this alternative is that the aerospace firms have not previously diversified into commercial markets. Their marketing operations are geared to government markets (and commercial airlines) rather than consumer markets, and it is difficult to evolve a whole new philosophy when the top management must, of necessity, continue to be attuned to the government market. Another description of this situation is that, like any other firm, an aerospace firm has a list of potential projects that it can arrange in order of expected profitability. Because the firm is attuned to the government market, its most profitable opportunities with the least uncertainty will normally be those for government markets. It therefore will not choose to develop new products for commercial markets, because it has better investment opportunities.

2. Tax incentives for R&D.

   The weakness of this alternative is that it does not necessarily induce firms to do R&D for the commercial markets of interest. Firms will first redefine existing activities as R&D, in order to receive favorable tax treatment, and then if they are induced to do additional R&D, it will quite properly be for whatever projects have the highest expected profit. In the case of aerospace firms these projects will almost certainly be projects that will enhance their positions in their most profitable markets, the government markets they know best.

3. Government sponsored commercial R&D.

   This alternative overcomes the aerospace firms' preference for government markets by providing subsidies for commercial product planning and development. However, it introduces two serious flaws into the product planning process. First,

it puts government managers into the central role of project definition and selection. It is very unlikely that government managers with an adequate knowledge of commercial markets will be found for this job. Second, it forces the product planning process into the open, competitive bidding mode of government contracting. A key element of commercial product planning and development is secrecy. The advantage that secrecy gives to the producer of a new product is a short-term limited monopoly in the marketplace. The duration of the monopoly can be extended through the patent laws for some kinds of new products, but many new products are not patentable. The loss of secrecy involved in typical government contracting would result in many of the best ideas for new commercial products not being submitted.

4. Government product planning and development.

An entirely in-house government product planning and development operation might be more effective than the combined government-industry contract-based arrangement for this type of development. However, if NASA were to successfully develop a commercial product, it would still have the problem of transferring it to the private sector. And if the operation were successful, it would be seen as competing with industry and would be put under political pressure to convert to some other mode of operation.

5. A space research and development corporation.

The only alternative that appears to have any chance of doing better than the leave it to the aerospace firms option is the private sector research and development corporation, set up and initially financed with federal funds, but having a long-term objective of self-financing.

The key advantages of this type of organization would be its ability to leave the entire product planning process to industry and its ability to protect the confidentiality of ideas submitted to it. It would not be required to go out for competitive bids, and it would, therefore, not have to define the new product, write specifications, or otherwise inject itself into the product planning process. It would simply have to make judgments as to whether unsolicited proposals submitted to it should be funded. Its ability to maintain confidentiality of the ideas submitted to it would strongly influence the kinds of proposals it would receive. If operated successfully, it would provide support for the projects with the largest expected revenues and profits.

It is impossible at this time to predict the size of this market. Once established, however, it is quite possible that this market would no longer need the stimulus of this type of corporation. For the present, however, it appears that the uncertainty of profits in this market, combined with the large investment per project that is to be expected, will result in underinvestment in this market by the only U.S. firms that are able to enter it successfully. An initial look at this option suggests that the private research and development corporation, with initial financing from federal funds, has the potential for successfully stimulating private sector entry into this market.

The Fuqua Bill

H.R. 14297, a bill introduced on October 12, 1978 by Mr. Fuqua, proposes a "Space Industrialization Corporation" to assist in the development of new products, processes, and industries using the properties of the space environment. The bill provides for the corporation to provide funds "to industrial ventures under negotiated management plans, with repayment including a profit being required of profitable ventures." This provision follows the plan of British and Japanese corporations that have been organized in the same way in order to supply long-term funding for the corporation. It also incorporates the important concept of negotiation rather than competitive bids. A sum of $50 million per year for two years is proposed to get the corporation started. Further funding could be voted. The Fuqua plan creates a corporation that is an agency of the federal government, but provides that it can be converted into a publicly owned private corporation.

Such a plan would clearly fit the description of the space research and development corporation in the preceding section. It has all the essential features of this organizational option that should make it capable of successful technology transfer.

Conclusions

The organizational option of the space research and development corporation appears to offer a significant opportunity for a new approach to technology transfer of space technology to commercial

markets. The Fuqua bill provides a specific implementation of this option that appears to include all features essential to successful operation. A study of variations on the approach used in the Fuqua bill could yield an understanding of some of the tradeoffs that have been made in arriving at this specific organizational form and perhaps result in some suggestions for improvements.

THE ECONOMIC BASIS FOR NATIONAL SCIENCE AND TECHNOLOGY POLICY

Donald A. Dunn
October 1979

Abstract

National science and technology policy is concerned with social choices about the rates and directions of technological change and the adoption and use of new technology. Such policy choices occur primarily in connection with management of the creation, dissemination, and use of scientific and technical information. Two categories of policy instruments are discussed: (1) market-oriented approaches; and (2) direct public action. This paper is primarily concerned with pointing out possibilities for increased use of market-oriented approaches that can provide benefits to society in the form of an increased rate of innovation and of more "appropriate" technology, better suited to the needs of consumers.

THE ECONOMIC BASIS FOR NATIONAL SCIENCE AND TECHNOLOGY POLICY

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National Aeronautics and Space Administration

Contract NASW 3204

PROGRAM IN INFORMATION POLICY

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Abstract

National science and technology policy is concerned with societal choices with respect to the rate and directions of technological change and the adoption and use of new technology in society. Such policy choices occur primarily in connection with management of the creation, dissemination, and use of scientific and technical information. Two categories of policy instruments are discussed: (1) market-oriented approaches; and (2) direct public action. This paper is primarily concerned with pointing out possibilities for increased use of market-oriented approaches that can provide benefits to society in the form of an increased rate of innovation and of more "appropriate" technology, better suited to the needs of consumers.

1.0 INTRODUCTION

National science and technology policy is concerned with societal choices with respect to technological change and the adoption and use of new technology in society. The creation of new technology can be viewed as the creation of new knowledge or information through research and invention. Invention and research, in turn, draw on previous work, and a society's policies with respect to the storage, retrieval, and dissemination of scientific and technical information are important elements of national science and technology policy. The adoption and use of new technology in society can be influenced in many ways by government policies and actions that deal with questions of access to or the provision of information concerning the new technology to users. This paper is concerned with all three stages of the information production-consumption process in the science and technology field: creation, dissemination, and use.

A government agency, such as NASA, is involved with all three stages of the information production and consumption process in its own field of space science and technology. It creates new information through its research and development programs. It disseminates this information and assists nonaerospace firms and various government agencies in making use of this information through its technology transfer program. And NASA is also, of course, a user of both NASA-created and other information in its own research and development programs. A private sector firm is also typically involved in all stages of this process in its own field of activity.

The objectives of national science and technology policy have traditionally been thought of in terms of increasing economic efficiency, productivity, and GNP. These overall national economic objectives can each be affected by changes in policy with respect to creation, dissemination, and use of scientific and technological information, and a number of these connections will be discussed here.

Efficiency, productivity, and GNP are all quantities that are independent of what is being produced. By focusing on these economic measures it is implicitly assumed that the national output is produced in properly functioning markets, in which the goods and services that are preferred by consumers are being provided. Of course, only a portion of the national output is produced in properly functioning markets in the U.S. or any other country. If only a small fraction of the GNP is produced outside of properly functioning markets, the effects of ignoring the nonmarket sectors in developing science and technology policy may not be serious. However, the U.S. economy has become a nonmarket economy in many of its major sectors, and it is doubtful if these sectors can be ignored in future planning. Several types of deviations from a free market exist, and some of their implications for science and technology policy will be discussed. Those deviations of special interest here are: (1) monopoly; (2) government regulation; (3) government provision of services; and (4) the fact that the principal costs of provision of services are being incurred by users rather than providers. As a result of these deviations from a free market, the validity of focusing primarily on productivity and GNP when seeking to formulate national science and technology policy becomes doubtful. An

attempt is made here to suggest some more relevant measures of economic performance, but these suggestions can only be viewed as preliminary at this stage.

The growth rate of productivity has been decreasing in the 1970's in the U.S., while this quantity, along with the real GNP, has continued to increase in Japan, West Germany, and some other nations [1]. Economic (GNP) growth in the U.S. has been primarily a result of an increase in productivity and only in small measure a result of capital investment [2], [3]. The factors that influence productivity are therefore of considerable interest. The entire subject is confused by the use of noncomparable measures and by the aggregation of sectors of the economy, such as manufacturing and services, that may have widely different rates of change of productivity. However, in the period 1900-1960 steady productivity increases in both manufacturing and agriculture occurred. Denison has put forward the hypothesis that, since schooling increased in the U.S. during these years of productivity increase, schooling was responsible for the increase [4]. A more persuasive argument put forward by Klein is that productivity increased as a result of innovation in dynamically changing competitive U.S. markets [5]. Klein's argument is that the U.S. market is now less competitive and that, since firms feel less pressure to innovate, there is less innovation and consequently a reduced rate of increase in productivity. Causes of the decline in competitive markets can be found in the increased roles in the economy of industries subject to regulation, industries with highly concentrated market structures, and governmental provision of services.

In addition, it has been widely observed that the U.S. is now an "information economy," in the sense that more than half of our paid workers and our economy is now engaged in the production of information-related products or services [6], [7], [8]. Information is not like other economic goods, because new ideas can be copied, usually at a much lower cost than the cost of creation. Therefore, the cost of creation of a new idea, through investment in basic research, for example, may not be appropriable, and potential investors will tend to underinvest in basic research for this reason. When we speak of underinvestment in this connection, we mean, relative to the amount of investment that would be socially optimal. Society receives benefits that go beyond the benefits received by the consumers of education and the firms that do basic research. It is therefore in society's interest to intervene in the markets for innovation, information creation, and education through government subsidies or by creating incentives for enhanced investment in these activities in the private sector. Various governmental actions have been taken to make investment in innovation more attractive, including patent, copyright, and tax incentives. Direct public support of basic research and education is also a traditional part of national science and technology policy. It is not at all clear that reliance on these traditional policies will be the most effective national policy in the years to come.

Perhaps the most significant deviation from a market economy in the U.S. is a result of the existence of the "household economy" in which the final output of the market economy is combined with user

time to produce the services that users ultimately consume [9], [10]. The existence of the household economy is not a form of market failure, but its existence raises a question, familiar in system analysis, of possible suboptimization through a focus on the market economy portion of the total system, rather than on the total system which includes both the market economy and the household economy. If the household economy were small in comparison with the market economy, a policy focus on the market economy might be justified. However, in the U.S., the household economy is comparable to the size of the market economy [9]. Therefore, it may turn out to be very important to consider the effects of science and technology policy on the household economy along with its effects on the market economy.

2.0 THE PRODUCTION AND CONSUMPTION OF SCIENTIFIC AND TECHNOLOGICAL INFORMATION

The information production-consumption process can be thought of as beginning with the creation of new information and proceeding through a dissemination process to the user who then consumes the information or uses it, possibly in creating a further innovation. An innovation that is brought to the market often includes both a new technology and a new concept of how this new technology can be utilized. Innovations often create new information that is disseminated and incorporated in other new products or services, etc.

There are three main policy instruments that have been used to encourage individuals and firms to create, disseminate, and utilize new information: (1) patents and copyrights; (2) direct funding of

research, development, and production by the government; and (3) subsidizing and other facilitating private sector investment in innovation and related activities. These policy instruments will be discussed in the following.

2.1 Patents and Copyrights

When we think of the individual inventor or creator of a new work of art, it is easy to see the economic effects of granting a patent or copyright to this individual. The patented invention or copyrighted work is protected against copying for some period of years and is thus made more valuable and more readily sold, and this increased value creates an incentive for further investing in innovation and invention.

There is an apparent tension between the policy objectives of obtaining a high national level of creativity and the policy objective of obtaining rapid dissemination of the results of the creative process. The policy instruments, such as copyright laws, that have been used to encourage creativity do so by creating barriers to copying and apparently act as obstacles to rapid dissemination. However, the tension is primarily a tension between short and long run objectives. In the short run, an innovation can perhaps be most rapidly disseminated by allowing free access to it. But in the long run, it is necessary to be concerned not only with dissemination of known ideas, but also with the continued creation of new ideas, so there will be something to disseminate. Patents and copyrights encourage both innovation and the disclosure of innovation. The alternative of

allowing free dissemination results in innovations being kept secret as far as possible, which obviously does not promote dissemination. Even under a property right system, many innovations, such as computer software, are not protected, and innovators often go to considerable lengths to keep their ideas secret [11], [12].

The effects of patent laws on the operation of a modern, competitive industrial market can be rather different from the effects on individual inventors. In modern industry, the invention process has been commercialized. Inventors are hired and organized to create new ideas that will be most beneficial to the firms that employ them. In some markets the innovation process has been accelerated to a very high pace. The computer industry is an example of an industry with a rapid development cycle; typically less than 5 years for a major innovation. A rapid obsolescence of products naturally accompanies this rapid introduction of new products. Five-year old computers may work very well, but their value is only a small fraction of their purchase price.

An important distinction needs to be made between the invention process that may be involved in creating a new product and the innovation process that is concerned with selecting the specific characteristics and technology of the new product and bringing it to the marketplace. Many innovations are not patentable. But innovation is protected by trade secret law and by the time it takes to copy a new product. In a high technology field, the time to copy may be over a year, and a firm that is a year or two behind its competitors may find

that its competitors have written off the costs of creation by the time its product reaches the market, so it does not gain a price advantage through copying. In such a market, copying would not be a successful strategy. The role of patents in such a market is unclear. Patents on basic inventions that will be used in several cycles of innovation have long-term value. Patents on obsolete products are obviously not of value. The usual argument that firms will underinvest in innovation does not seem to apply to rapidly changing, high technology markets. Firms in these markets must innovate in order to survive. Firms can effectively nullify the effects of patents by entering into cross-licensing agreements. Firms, in effect, give up the potential rewards from occasional basic patents in order to avoid the risk of competitors' inventions blocking their access to the market. Of course, cross-licensing and patent pools can violate the antitrust laws [13]. But if all new entrants to an industry can join the licensing agreements, the effects are not anticompetitive.

The economics of invention and innovation in markets with rapidly changing technology appears to be an important field for research [14]. Neither the operation of such markets without government intervention nor the effects of patents and cross-licensing agreements in such markets are now well understood.

2.2 Direct Funding of the Creation of New Information

As an alternative to creating property rights in new information through patents and copyrights, direct public investment can be made

in the creation of new information. In areas in which the government has a mission responsibility, as in defense and space, it can be expected to support the research that it believes will be most beneficial to its missions in the long run. In areas in which the private sector is responsible for providing products and services to consumers, there is also a potential role for government supported research, especially basic research. The economic argument that firms will underinvest in research that leads to inventions subject to copying is even more applicable to basic research that is aimed at understanding nature, because patents do not cover theories or laws of nature. Thus, the discoveries that come from basic research will benefit a firm's competitors as much as the firm itself (except for public relations benefits), so the amount of basic research done in the private sector will tend to be less than is socially optimal [15], [16]. Some form of governmental intervention in the market, in order to create increased incentives for carrying out basic research, is therefore appropriate. And direct government funding is a straightforward way to support basic research.

Once government funding of research is adopted as a national policy, a question arises with respect to the ownership of patents and copyrights on innovations made in this research. Presumably, the national interest is best served by a government patent policy that will maximize innovation. Government ownership of patents results in disclosure, but it does not create incentives for firms to make the necessary investments to bring these patented innovations to the market. Granting of exclusive rights to firms that do make such

investments would enhance the incentives to develop these innovations, much as homestead rights have been used to encourage the development of government land.

Another important policy issue in this area is that of the allocation of funds. What areas of research should receive funding, and at what levels? A balance of many diverse interests is somehow achieved in the present system. However, there may be opportunities for improving the present system, for example, by creating more independent sources of research funding that are likely to support research leading in new directions. Both industry and mission-oriented agencies could strengthen their positions in the long term by supporting basic research projects of special interest to them, rather than relying on others to provide this support.

2.3 Facilitating Private Sector Investment in the Creation of New Information

Industrial investment in research can be increased through tax incentives. However, there is the risk that the amount of new research may be small in relation to the amount of tax subsidy, because firms have an incentive to reclassify existing activities to quality for favorable tax treatment as well as to initiate new research.

Also of importance is the possibility of more industry-sponsored research, on an industry-wide basis, in universities, industrial research labs, or research institutes. There are likely to be many cases arising in the future in which it is important for an entire industry to develop a new set of techniques that will be used throughout the industry. Projects to develop these techniques could appro-

priately be funded and managed by the concerned industries themselves, without governmental intervention. Industry cooperation in such research programs could, however, have antitrust implications, and it is possible that new legislation would be helpful in encouraging this type of industry-wide research activity.

The principal limitation on industry-wide research is the competitive nature of industrial firms and the desire by each firm for secrecy and the exclusive use of new ideas created by an individual firm. However, there are precedents for this sort of industry cooperation in many industries. The necessary condition for a successful program of this type is a guarantee of access to all outputs of the program to all industrial participants in the program. This condition can best be met by carrying out the research in universities or non-profit institutions, separate to some extent from the firms. It would be difficult to create a successful program that would employ scientists and engineers from the participating firms in the direct conduct of the cooperative research. On the other hand, from a national policy standpoint, a central feature of this approach would be the participation of scientists and design and development engineers from industry in project selection and the directions to be taken in the research done under the program. The incentive for firms to provide this costly participation in the management of the research program would be stronger under an industry-financed program than a tax-supported program.

2.4 Facilitating Private Sector Innovation

The production-use cycle can be entered at the use end rather than the creation end. Policy instruments can be designed to facilitate

the use of existing information in the process of bringing a new product or service to the market, i.e. in the innovation and product planning process. NASA's technology transfer program is designed to assist government agencies and industrial firms in the nonaerospace sectors of the economy in making use of new technology that has been created in the space program and that has promise for utilization in other sectors of the economy.

The policy instruments used by NASA include: (1) creating information "bulletins" or abstracts that describe the new technologies believed to have significant potential in nonaerospace applications and making these abstracts readily available to U.S. industry and government agencies; (2) assisting nonaerospace users in the product planning process, for example by going beyond an information abstract to a complete business plan for the adaptation of a NASA-developed technology to a specific commercial application. This latter form of technology transfer obviously requires careful project selection, because there may be hundreds of possible products or services that could be developed from a specific NASA technology. However, it has the important value that it creates an example that is specific enough to present potential users with a much more complete picture of the possibilities than a simple description of the technology itself. Even if the sample business plan is not adopted, it could stimulate a user to create a business plan that would be adopted. The technology transfer process is not well understood, but it seems reasonable that it might be economically efficient to go somewhat beyond the basic abstract and document dissemination process.

What is unclear is just how far and in what ways it is efficient for an agency like NASA to enter into the product planning process.

A somewhat different approach to technology transfer is to provide a subsidy to firms willing to undertake product planning and development of products that would use certain classes of technologies or that would provide products or services of certain desired types. Both Japan and England have experimented with this approach, using a "national research and development corporation" as the organizational entity for carrying out this idea. Rep. Fuqua has introduced a bill that would create a U.S. quasi-governmental corporation to encourage the development of new products, processes, and industries using the properties of the space environment [17]. The bill provides for the "space industrialization corporation" to provide funds to industrial ventures under negotiated management plans, with repayment including a profit being required of profitable ventures. This provision follows the plan of British and Japanese corporations that have been organized in the same way with repayment only required from profitable ventures. It also incorporates the important concept of allowing negotiation rather than requiring competitive bids. A sum of $50 million per year for two years is proposed to get the corporation started. Further funding could be voted. The Fuqua plan creates a corporation that would initially be an agency of the federal government, but provides that it can be converted into a publicly owned private corporation.

A significant advantage of this approach to technology transfer is that it would leave the entire product planning process to industry,

where it can be done best, and it does so in a way that protects the confidentiality of the ideas submitted in proposals. The research and development corporation would not be required to use the competitive bid approach and hence would not have to define the product or otherwise inject itself into the product planning process. It would only have to select which proposals to support. If it maintained confidentiality of the proposals submitted, it could expect to receive proposals with the best available innovative concepts that industry could present. The economic justification for this approach in a market such as the industrialization of space is the uncertainty of profits, combined with very large investment per project required, in a market that would offer long term benefits to the U.S. by maintaining the comparative advantage the U.S. has developed in space technology and applications. There is no reason that this approach could not be used for "market development" programs in a wide variety of fields.

3.0 IMPROVING THE OPERATION OF MARKETS IN ORDER TO ENCOURAGE INNOVATION THAT IS RESPONSIVE TO CONSUMER DEMAND

It has become apparent in recent years that industries with a high degree of concentration, with strong local monopolies, or with high barriers to entry more often than not achieve their protection from competition through government action [18]. Industries that consist of a few large firms seem to have less incentive to innovate, if it is difficult for small competitors to enter their market with innovative new products. In industries where small competitors can enter the

market rather easily, as in the computer industry, small firms provide a very large fraction of the innovation that occurs.

Four major types of policy options are considered here that are of interest in dealing with industries that have somehow managed to obtain governmental protection from competition: (1) deregulation in "regulated industries" such as railroads; (2) deregulation in "unregulated" markets; (3) improved consumer information in all markets, but especially in local service markets; and (4) privatization of markets dominated by government providers of service.

3.1 Deregulation of "regulated industries"

Although government regulation is often adopted as a consumer protection measure, the eventual effect is usually to limit competition by creating barriers to entry to the regulated market [19]. The pace of technological change in regulated markets is slowed for a number of reasons. Governmental approval may be required to make new investments of certain types, and the regulatory process can be used to prevent an innovative firm in a regulated market from introducing new technology as fast as it would like. Once new technology is in place, the regulatory process can be used to prevent pricing services that use the technology in ways that would threaten less innovative service providers. In addition, regulators and regulated industries may adopt pricing strategies that minimize present prices but slow the introduction of new technology that would reduce prices in the future. Only in markets where competition is restrained by government action can these anti-innovation policies be pursued and sustained for long periods of time.

A government can, thus, through its own actions, create a competitive disadvantage for its industries in world markets. Of course, governments do not act to regulate an industry without the consent of the industry, and usually governments are pushed into regulation by industry, in order to limit competition [20]. However, when new national policies to encourage innovation are being considered, it is difficult to think of a more significant policy option than deregulation, in industries presently subject to regulation [21].

This argument does not depend on economic studies of innovation as a function of firm size or market structure. A number of studies have been made of the various economic characteristics of firms, in an attempt to identify market conditions favorable to innovation. It has been suggested that large firms may be more apt to innovate than small firms, because they have more flexible resources [22]. Firms in competitive markets that are not too fragmented have been found to be more innovative than firms in either highly concentrated markets or markets with a large number of very small firms [23]. However, the rate of innovation is also strongly a function of the specific industry and its stage of evolution [24]. Regulation could be used to influence firm size or market structure, but its direct effects on innovation are, in the author's opinion, much stronger than any of the other market characteristics that have been studied. And the evidence is that regulation is consistently used to slow the pace of innovation. For example, the rate of innovation in the business telephone terminal market was extremely slow when this market was protected from competition. The Carterfone decision in 1968 opened this market to competition, and

there has been a high rate of innovation since that date, both by AT&T and its new competitors [25], [26]. The opportunity exists to increase innovation through deregulation in many other U.S. industries.

Deregulation would not only tend to benefit consumers through an increase in the availability of new products and services, but also through reduced prices for existing services resulting from process innovation. Perhaps equally important in the long term would be the improved position of the U.S. in world markets in the deregulated industries. In many cases regulated industries in the U.S. are industries that are completely govermentally managed in other countries, such as railroads, telephones, and broadcasting. Thus, even though technological change in these industries has been limited by regulation in the U.S., it has also been slowed in other countries by even more constraining governmental action. Therefore, the U.S. is not yet at a competitive disadvantage in most of these areas. And the opportunity to take or maintain the lead in these areas is still open.

As these markets are deregulated and start to admit innovation at an increased rate, foreign equipment suppliers will be attracted to these markets along with U.S. suppliers. Pressures will then undoubtedly develop to protect U.S. equipment suppliers from foreign competition. Protectionism in these markets will be more easily justified, if foreign markets of the same types are not open to U.S. industry, as is almost certainly going to be the case initially. In the long term, however, international competition may cause deregulation worldwide, if it is initiated by the U.S. and if deregulation does lead to more rapid technological change. A more rapid rate of technological change in the

U.S. and an improvement in the relative position of U.S. firms in these industries relative to foreign firms may create pressure for deregulation worldwide as a competitive response.

The trend toward more rapid diffusion of innovation throughout unregulated world markets has been widely noted. Lower wage costs in developing countries make them competitive sources of manufactured goods, thus putting more pressure on the developed countries to increase the pace of innovation. At the same time, the growing world markets are making it easier to write off R&D expenses and to finance innovation. The deregulation of U.S. regulated markets would simply be another step in this process.

3.2 Deregulation in "unregulated" markets

Many industries that are not regulated in the sense that public utilities are regulated are nevertheless neither competitive nor innovative. Usually these industries are highly concentrated and the role of government in these industries is often anticompetitive, even though less obviously so than in the case of public utilities.

For example, in the drug industry the government plays a complex role. In connection with prescription drugs, advertising of prices and the introduction of generic drugs would obviously increase competition. The high cost of testing new drugs creates a barrier to entry by new smaller firms. Government policies aimed at increasing competition could encourage innovation in this industry.

The broadcasting industry plays a key role in the economy. It is not regulated in the way that public utilities are regulated. A market

in broadcast stations exists; entry is possible through purchase of an existing station. But government plays a central role in limiting competition and the operation of the market in this industry [20]. For example, pay-by-program television has been technically feasible since the late 1950's. But the introduction of pay television into the broadcast market would create economic risks for the existing networks and stations. Their markets have been protected from pay television competition up to the present time by restrictive FCC rules and the administration of those rules, even though it makes no more economic sense to ban pay television than it would to prevent magazines from charging consumers for copies and allow only magazines that relied exclusively on advertising for their revenues to exist.

There are many opportunities to increase competition and innovation in unregulated U.S. industries, simply by withdrawing governmental support for anticompetitive practices in these industries. Thus, the science and technology policy option of greatest significance in many industries today is simply the option of repealing previous legislation. This statement has many detailed implications that differ from industry to industry. And each industry would require a major study and analysis effort, as well as a political consensus sufficient to overcome industry opposition to deregulation, in order to implement a deregulation policy option. That such an option is worth considering has been demonstrated by airline deregulation.

3.3 Consumer Information

A well functioning market requires that consumers have adequate information about price and quality. Otherwise, competition cannot exist. Yet, in many consumer markets, the consumer not only has inadequate knowledge of product quality, but also has difficulty obtaining even price information. Most advertising is not intended to provide this type of information, but rather to inform consumers of the existence of products, sources of services and products, and to create favorable impressions of the advertised product or service. While Consumers Union provides comparative information of the type that consumers need on nationally advertised products, very little information is available on the local services and products that consume most of the consumer's income: housing, medical services, auto repair service, and other local services.

It is not reasonable to expect either government or industry to provide the type of information that consumers need. The job will almost certainly have to be done by consumer groups, if it is to be done at all. Nevertheless, the opportunity exists for government to facilitate the development of consumer information services. It is reasonable to expect very substantial gains in the productivity of local services, as well as a much more rapid rate of innovation in these industries, as a result of increased competition that would result from improved consumer information at the local level [27], [28].

3.4 Privatization

In many sectors of the economy the government acts as a monopoly or near-monopoly provider of services. The postal service, the public

schools, public libraries, defense, and the exploration of space are some of the major markets dominated by government or quasi-government providers. One of the sources of difficulty in these markets is the fact that services are provided to users at zero price. Funds are obtained for the provision of these services through general taxation, and these funds are allocated to the service provider by Congress or a state legislature. Such organizations become attuned to the wishes of their legislative constituents, but their incentives to serve their users are weak and exist only to the extent that their users make their demands felt by their representatives in the legislature. In some cases, this system is quite satisfactory. When the users are industrial firms, the likelihood is high that the legislature will adequately represent the interests of the user in dealings with the government service provider. However, when users are individuals, it is difficult for the users to arrange for their interests to be adequately represented. A policy option that is, in principle, easy to adopt is to charge users directly for the service, rather than to use tax funds to pay for the service. The principal benefit of this approach is that service providers become more attentive to their customers. However, this approach does not benefit users to the full extent possible unless users have an alternative supplier to turn to. Thus, the postal service feels some pressure from the threat that users will reduce their purchases of service, but the pressure is much greater, if users can get their packages or messages delivered by an alternative service provider such as United Parcel Service. Thus, the combination of funding through direct user payments with opening

the market to competitors avoids the principal difficulties with government provision of service. But there is still one difficulty with such a market, and that is the fact that both government and private sector monopoly service providers tend not to price their services in proportion to cost. In other words, they subsidize one service from revenues obtained from another service. Such cross-subsidies are often introduced in response to their legislative constituents [29]. Once in existence, such cross-subsidies are politically difficult to eliminate, and their existence can block the adoption of open entry policies that threaten to force the market toward cost-based pricing. An example is the subsidy of rural mail delivery by urban mail. The only satisfactory way of preserving such subsidies is to make them into direct subsidies. However, direct subsidies are more difficult to get political support for; their economic and social effects are often examined more closely than are the effects of indirect subsidies. For example, should rural mail and telephone subsidies be extended to both rich and poor rural dwellers, and, if not, how could the distinction be made on a practical basis?

If a direct subsidy is acceptable politically, as it might be in the case of low income users of public schools and libraries, it can be combined with a direct user payment system by providing vouchers to the low income users [30]. But again, such a system is only fully effective if the user can turn to an alternate source of service if unsatisfied. Once free entry is allowed, along with cost-based pricing and direct user payment, the need for a government service provider often disappears altogether. The only residual trace of

government intervention would then be the provision of vouchers or scholarships to low income individuals. In such a case, full "privatization" of the service can be accomplished.

In defense and space, the path to privatization is not as straightforward as it is in the case of purely domestic services. Nevertheless, in both defense and space in the U.S., the government relies on the private sector for its hardware, software, and some of its operational services, so some elements of privatization are present in these services. The opportunity for further privatization may exist in defense and space, and analysis of this possibility appears to be appropriate. The directions in which innovation in these fields is moving is now determined by a process in which the individual consumer plays almost no role whatsoever. It is not easy to bring the consumer into these fields effectively. A token, uninformed consumer on an advisory board is not an effective mechanism for getting consumer "input." One possibility that has not been adequately explored is the idea of improving consumer-oriented information about the operation and significance of these agencies. Of course, both agencies now spend substantial sums on providing information to consumers, but this information is organized and presented in a way that is likely to strengthen public support for existing programs. The new possibility is to provide information that will cause consumers to question the basic premises and orientation of existing programs and to see some of the options for defense and space that are not now given official support. It is quite possible that a more open, questioning approach to defense and space policy would result in more innovation and more effective programs in the long term.

4.0 IMPROVING THE MANAGEMENT OF GOVERNMENT SPONSORED RESEARCH AND DEVELOPMENT

The market concepts discussed in previous sections have some bearing on the questions of the appropriateness of government sponsorship of R&D and of how project selection in government sponsored R&D should be carried out.

Starting with basic research, there seems to be little controversy over the appropriateness of some form of governmental stimulus to this activity, whether through direct support, patent and copyright protection, or tax incentives. The project selection mechanism is now fairly diverse, and there are many reasons for favoring a diversity-oriented approach to funding and project selection. The economic concept that is relevant here is that the customers or users of basic research should be involved in project selection and funding, by analogy to the role of the consumer in markets. This concept is only occasionally operative today. A possible example of the application of this principle would be to bring product development engineers into the project selection process in the support of research projects in their field at an agency like NSF. This group now influences, to some extent, the paths of basic research within their own companies. It might be feasible to increase their influence in government sponsored programs as well, on the basis that they are the most direc nsumers of basic research. The ordinary individual is the ultimate consumer of basic research, and again the only realistic opportunity for increasing consumer participation appears to be through improved consumer information on the basic research establishment and its operation.

Considering next the role of government in relation to applied research and development, the appropriate role is fairly clear in areas in which the government has a mission responsibility and monopoly, such as defense and space. In these areas the government is responsible for funding, project selection, and overall management. The possibility of increasing the degree of privatization and through this, competition and innovation, was discussed above. In civilian markets, there may also be a role for government sponsored applied research and development, but the case is less clear. If there is an appropriate role for government sponsored R&D in civilian markets, it is probably primarily in applied research, because product development is closely tied to the market and is best done by firms that are familiar with the market [31].

Applied research is research that is oriented toward specific applications in specific markets. It is often clear that a specific type of device or technique is of key importance in the evolution of a particular field, and it is clear that the best way to promote progress in this field is through the development of specific devices or examples of the critical technique. In such cases this development is not coupled directly to the market, but rather represents learning work that goes beyond basic research and prepares the way for market-oriented development to follow. An example might be a key component in a large system, such as a new type of communication satellite that would make possible an improved communication system. In such cases, there may well be a case for government sponsorship of R&D on the economic grounds that the private sector tends to underinvest in this

type of work, because it is unable to appropriate the results. A firm is likely to underinvest in applied research that could benefit its competitors as much as itself; it will prefer to wait until there is a specific market opportunity to focus its work on. Thus, if the government can find these critical areas of applied research, it can probably make an important contribution to the national competitive position in whatever industries it chooses to support.

The process by which areas of government applied research are chosen is thus an important element of the R&D program. It may be that there are opportunities for organizational improvments in the project selection process. At the present time, U.S. government agencies have advisory panels that help them to keep in touch with the industry and its views. A possible opportunity for improvement might lie in the way industry representatives are chosen for these panels or in the ways that panel members are able to express their views. In some cases an industry panelist may know of an area that would be productive for government R&D, but may be reluctant to share his ideas with his competitors. There may be an organizational alternative that would allow secrecy to be maintained. For example, if the R&D is government sponsored but done in industry, a negotiated contract rather than a competitive procurement could protect the ideas of the industry R&D group. Of course, this approach would violate many of the existing constraints on government contracting. An alternative to this approach is the creation of tax incentives for R&D, under which firms would make project selections completely on their own [31]. The weakness of this approach is that it results in the

support of a great deal of work that industry defines as R&D for tax purposes, but that may be nothing more than restyling, as in the automobile industry.

One way of looking at government R&D in civilian markets is that the government is acting as an industry-wide cooperative R&D agency. A portion of the industry's corporate income tax can be thought of as being allocated to this purpose, and it is therefore reasonable to expect R&D project selection to be made by industry. In order to avoid the weaknesses of both government sponsored R&D and the tax incentive approach, it might be possible to encourage the development of industry-wide R&D activities outside of government, as discussed in Section 2.3. The "national research and development corporation" concept discussed in Section 2.4 is another option that allows greater confidentiality than a government sponsored program with consequent increased flexibility and potential for innovation.

5.0 INCREASING "APPROPRIATE" INNOVATION IN LARGE-SCALE SYSTEMS

Starting with Jacques Ellul [32], there has been a steady flow of literature concerned with the uncontrolled, apparently autonomous evolution of technology in directions that are "inappropriate" because they are not directions that benefit consumers [33], [34]. The principal contribution of economic theory to this question is to suggest that these "inappropriate" evolutionary trends in technology are most likely to occur in sectors of the economy in which market forces are ineffective, often as a result of governmental action. For example, the choice of new

technology in U.S. hospitals is not limited by considerations of economic efficiency, because insurance payment systems cover all costs and there is no effective competition in this market. The result has been an extraordinary rise in hospital costs [35].

System analysis can contribute to an understanding of these trends by pointing to examples of inappropriate technology in areas in which large-scale societal systems are being built with inadequate coordination and planning, such that "suboptimization" is taking place. The subsystems of these inappropriate systems are being optimized, but no one is looking after the overall system optimization. For example, in attempts to increase productivity in post-secondary education, televised classes have been used to increase the number of students per teacher. Television and other educational technologies such as audio cassettes used in combination with still visuals have been found to have no significant difference from each other and from live classes in their effects on student performance. When optimization of the school's operation through minimization of teaching costs is done, television appears to be the preferred technology. However, if optimization of the entire learning operation, including the cost of student time, is done, technologies such as audio or video cassettes that offer students the chance to listen to lectures when they wish and to review them as often as they wish, result in lower total costs. The optimization of the school's productivity is a suboptimization, because it fails to include the students in the system and the costs of student time that would be included in an overall system optimization. The system boundary in such a case has been incorrectly drawn, from the standpoint of society, even though correctly drawn from the standpoint of the school.

A similar suboptimization is taking place in some areas of national science and technology policy. Present policy focuses on productivity in the market economy and on GNP, the output of the market economy rather than on the output of the total economy. The total economy includes both the market economy and the household economy. In the U.S., the household economy is comparable to the size of the market economy, because for most services that consumers receive, the cost of consumer time is several times as large as the price that users pay into the market economy for goods and services [9], [10]. As in the case of educational technology, there is a danger that firms will choose the best technology from their standpoint and end up with the wrong technology from society's standpoint. Wrong choices by firms will be corrected in markets where users have a chance to obtain services from more than one provider. However, in fields such as education, medical care, defense, and space, where there are local or national monopolies, wrong choices are not automatically corrected.

One approach to science and technology policy that would improve technological choices in large-scale systems is, of course, to improve the operation of markets by increasing competition and consumer choice, as discussed in Section 3. When deregulation and competition are not feasible, it still may be possible to refocus technological choice toward options that will minimize total cost rather than provider cost and that will optimize total system operation rather than the subsystem under the control of the provider. Any new non-market approach to science and technology policy that seeks to induce overall system optimization will probably have to do so by facilitating large-scale system planning that does in fact take users into account in the organizational design.

For example, there are many opportunities for innovation in such areas as city design, in the organizational sense rather than the physical sense. In principle, such local service markets as housing, transportation, education, and policy services could be highly innovative. These markets are presently highly constrained by regulation and most are monopolistic. Both market incentive approaches, such as deregulation and privatization, and new organization designs that encourage overall system optimization could usefully be the subject of analysis and R&D.

6.0 CONCLUSIONS

Science and technology policy is concerned with the rate and directions of technological change in society. Two broad categories of policy instruments are available: (1) market-oriented approaches, such as the modification of property rights in newly created information through patent law, that seek to increase the incentives for the private sector to invest in R&D; (2) direct public action, such as government sponsorship of R&D, that seeks to substitute government action for the operation of the market. Much existing policy makes use of the direct action approach. This paper has been primarily concerned with pointing out possibilities for the use of market-oriented approaches and some of the advantages of such approaches that can be seen from basic economic principles.

The fundamental economic justification for government action to increase innovation in markets is that the private sector will tend to underinvest in R&D because it is not able to fully appropriate the benefits of such investments. The reason for this inappropriability is that the information that results from R&D can be copied by competitors and

the originating firm may, therefore, not be able to recover its costs of creation. In markets that are competitive and in which the industry is at a stage where technology is changing rapidly, investing in R&D is a necessary element for the survival of a producing firm. Innovations in such markets are protected by the fact that it takes a substantial time and effort for competitors to make copies. It is unlikely that firms underinvest in R&D in these markets, and further stimulus to innovation through governmental action is not needed.

In regulated markets and other markets in which barriers to entry are created by governmental action, there is often a variety of administrative obstacles to the introduction of innovation. Deregulation is the most effective mechanism for the stimulation of innovation in these industries.

The objectives of technological innovation for a nation are twofold: (1) to maintain or acquire a competitive position in the world market; (2) to provide better products and services to the citizens of the nation. Much of national science and technology policy can be justified by its effectiveness in contributing to the first objective. For example, the use of tax funds in support of education, basic research, and libraries contributes to the development of a national information infrastructure. This infrastructure creates the basis for comparative advantage in international trade in the information-based economies of the modern world. The mechanisms for government action in support of education, basic research, and libraries involve subsidies of these activities. The quality of these activities could probably be improved by giving more control over the character of the services offered to the users rather

than the providers of these services. The organizational approach to providing government support for industrial R&D could also probably be improved. Industry-wide R&D organizations within the government, in government corporations, and in private firms could provide similar services but with different degrees of industry control and confidentiality for innovative ideas.

In many large-scale systems, the evolution of technology has taken place in ways that have been characterized as "autonomous" and "inappropriate," because the technologies seem to have evolved in directions of their own, without regard for human needs. Much of the difficulty can be traced to the fact that these systems are monopolistic; users in these systems do not have an adequate choice. Market-incentive approaches such as deregulation and privatization, offer the most reliable path to the restoration of appropriate innovation. However, in certain areas, such as defense and space, a new approach to science and technology policy that seeks to achieve a more comprehensive approach to system planning may bring innovation that is more appropriate to human needs.

A general conclusion is that there seems to be a number of opportunities for increasing the rate of innovation and for bringing the directions of innovation more closely into line with the needs of users. Most of these opportunities can best be realized by improving the operation of markets by such techniques as deregulation, improving the quality of consumer information, and privatization. A second conclusion is that these improvements could benefit the consumer, both as a member of a nation with a stronger position in the world market and as a consumer of more "appropriate" technology. To obtain these benefits, various forms

of organizational innovation appear to be needed. Studies of new organizational options for the implementation of national science and technology policy would be an essential first step in this innovation process.

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AN INQUIRY INTO THE HOUSEHOLD ECONOMY

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Abstract

Production by consumers has been largely overlooked by economists, yet there is little doubt of its importance. All products and services are purchased by consumers in an unfinished state. The consumer must then do further processing to produce the good or service desired. Lancaster* and Becker have constructed theoretical outlines of this process, yet empirical work has been lacking.**

Each household may be viewed as a little corporation, purchasing a variety of inputs and producing a variety of goods and services for its members. The aggregate of these little corporations is referred to as "the household economy." Yet the economy, as it has been traditionally defined, usually includes only those goods or services produced in return for money payment. It is referred to as "the market economy" to emphasize this dichotomy.

This paper presents empirical evidence (based on a re-structuring of the national income accounts) that the household economy is comparable in economic importance to the market economy.

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** Gary S. Becker, "A Theory of the Allocation of Time," The Economic Journal, September, 1965, p. 493.

Most empirical studies in economics focus on the trading of goods and services, and hence, neglect to consider the value of goods and services produced by individuals for themselves and their families. This paper presents an empirical examination of this "household economy."

The principal result of the study is a comparison of the value of the time which people devote to each activity of their lives with the money they spend on the activity. After-tax wage rates are used to value an individual's time.

The enormous size of the household economy, and the fact that for most activities the value of the consumer's time devoted to an activity exceeds the money expenditures on the activity, suggest that there are many opportunities for productivity improvements in the household economy which have been overlooked in most traditional thinking on productivity.

AN INQUIRY INTO THE HOUSEHOLD ECONOMY

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Engineering-Economic Systems Department
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ABSTRACT

Most empirical studies in economics focus on the trading of goods and services, and hence neglect to consider the value of goods and services produced by individuals for themselves and their families. This paper presents an empirical examination of this "household economy".

The principle result of the study is a comparison of the value of the time which people devote to each activity of their lives with the money they spend on the activity. After-tax wage rates are used to value an individual's time.

The enormous size of the household economy, and the fact that for most activities the value of the consumer's time devoted to an activity exceeds the money expenditures on the activity, suggest that there are many opportunities for productivity improvements in the household economy which have been overlooked in most traditional thinking on productivity.

1. INTRODUCTION

Production by consumers has been largely overlooked by economists, yet there is little doubt of its importance. All products and services are purchased by consumers in an unfinished state. The consumer must then do further processing to produce the good or service desired. Lancaster[1] and Becker[2] have constructed theoretical outlines of this process, yet empirical work has been lacking.

Each household may be viewed as a little corporation, purchasing a variety of inputs and producing a variety of goods and services for its members. These little corporations may be thought of in the aggregate as 'the household economy.' Many outputs of the household economy, for example food preparation or clothes cleaning, differ little from the outputs of some conventional corporations. Yet the economy, as it has been traditionally defined, usually includes only those goods or services produced in return for money payment. It will be referred to here as "the market economy" to emphasize this dichotomy.

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[1]Kelvin J. Lancaster, 'A New Approach to Consumer Theory', <u>Journal of Political Economy</u>, Vol 74 (April, 1966), pp. 132-157.

[2]Gary S. Becker, 'A Theory of the Allocation of Time', <u>The Economic Journal</u>, September, 1965, p. 493.

The arbitraryness of the distinction between the two economies is painfully evident. If I pay you to clean my house, and you pay me to clean your house, then both transactions are in the market economy. If we each clean our own houses, or even clean each other's house as a favor, then the activities must be regarded as part of the household economy, as they certainly are not part of the market economy. The constant shifting of activities across the boundary between the two economies may result in misleading inferences. For example, if increasing numbers of women take jobs in the market economy and spend part of their income purchasing services, such as day care, which they used to produce for themselves in the household economy, then the usual measures of the economy, such as Gross National Product (GNP), will indicate a larger increase in production than has actually been the case.

However, this problem of activites shifting across the boundary between the two economies is only one symptom of the fact that a major portion of the economy is simply left out of most conventional economic analysis. This neglect of the household economy is reflected in government policies. In particular, the household economy is neglected in most present thinking on productivity. While much discussion, and some action, is devoted to improving productivity in the market economy, little attention is given to improving prod-

uctivity in the household economy. Yet it may be argued that improving the productivity of any activity in the household economy would have the same effects on welfare as improving the productivity of an industry of similar size in the market economy.

There are two reasons why the household economy has tended to be neglected by economists. The first has been a definitional problem. Although it is arbitrary, defining the economy to include only those goods or services produced in return for a money payment does create a sharp distinction between activities which are and are not part of the economy. Most alternative definitions require many judgemental distinctions before they can be applied in practice. The only solution would seem to be to regard every activity in which people engage as part of the economy. One may view every activity in which people engage as a service, even if only to the person who produces it.

The second problem is one of data. Data on money transactions are widely collected and distributed. Data on other types of activities are not so readily available. This study is an attempt to pull together available data on the various activities in the household economy, and express this data in money terms. It will be shown that many of the activities in the household economy are 'industries' of

enormous proportions. For most activities, the value of the time which people devote to the activity exceeds the money the people spend on the activity. Hence, the opportunities for productivity improvement in the household economy are great. Using this data, one may identify specific opportunities which merit futher study.

2. THE THEORY

Unfortunately, since household outputs are not sold, it is difficult to place a monetary value on them, so as to compare their value with those of outputs in the market economy. There is, however, one household output which is sold in the market economy--labor. According to economic theory, rational producers will allocate their scarce resources in such a way that the value of the marginal product of the resource is equal in each use. Applying this logic to the allocation of time in the household, it may be argued that time contributed by members of the household should be valued at the wage rate of each individual. Since personal time is really the only scarce resource contributed by the household, it seems reasonable to assume that the value added by the household in producing each good or service is equal to the value of time spent producing the good or service. The total value of each good or service produced by the household is equal to the value of time plus the value

of any inputs purchased in the market economy ('market expenditures') which were used in the activity.

There are at least two objections which may be made to this procedure. The first is that the time which is sold as labor may also produce a service (or disservice) to the individual involved, since people may derive pleasure (or displeasure) from their own labor. The wage rate will not reflect the value of this additional service (or disservice), and hence not be an accurate representation of the true value of peoples' time. Second, people may not be free to adjust their work hours so as to equate the value of the marginal product of time off the job to the wage rate. Unfortunately, there is, as yet, no way to correct for these problems in an empirical study.

Another troublesome problem with valueing peoples' time at the wage rate is that it works only for people who have wages. Perhaps the most notable class of people who would be left out under this scheme are housekeepers. Housekeepers are the professionals of the household economy, and should not be overlooked. As will be discussed below, data are available on time allocations by housewives, who comprise the overwhelming majority of housekeepers. It will be assumed that housewives have an opportuntity cost of time (i.e. the wage rate they could make if they were employed in

the market economy) equal to the after-tax wage rate of the average female year-round full-time employee. People who will have to be left out of this analysis due to lack of both time allocation data and the difficulty in estimating wage rates include children, retired people, and the unemployed.

Two major types of data were required by this project. The first type were data on individual time allocations. This data was taken from a 1965 study done by the Survey Research Center at the University of Michigan. For that study, about 2000 non-farm urban-dwellers between the ages of 18 and 65 kept diaries of how they spent a single day. Times reported were coded into one of 96 activity categories. Complete tables were then compiled of time allocations, in average number of minutes per day, for employed men, employed women, and housewives. Tables with less detailed 37 activity categories were also published for specific socio-economic groups, including six household income levels.

The second type of data were on market expenditures. These were taken from the U.S. Bureau of Labor Statistics' Consumer Expenditure Survey, which gives data on consumer expenditures broken down into several hundred categories. The survey was conducted in 1961-62 and again in 1972-73.

This study will use data from the 1972-73 survey, which although a bit more separated in time from the 1965 time allocation data, is more complete and up to date than the 1961-62 survey.

Reconciling the data on time allocations with the data on consumer expenditures poses several problems. First, it is necessary to reconcile the classifications of time allocations with the classifications of market expenditures. Every effort was made to develop as detailed a classification of household activities as the data would allow. A 38 activity classification was ultimately developed. The first 17 activites are what will be called "tradable" activities, since they are direct competitors with services which may be purchased in the market economy. The last 20 activites are called "non-tradable", since the services which result may be consumed only by the person who produces them. Appendix A describes the activity classification and the assumptions behind it in more detail.

The second data reconciliation problem was to find a way to compare data on <u>individual</u> allocations of time with <u>household</u> market expenditures. The solution is to work at the aggregate level. Thus, the sum total value of time devoted to a particular activity by all individuals may be compared to the sum total market expenditures by all households.

Breaking out the data by household income levels is difficult, as the necessary data on individual wage rates by household income class have not been published. These wage rates may be estimated, however. Appendix B explains the methodology which was used to accomplish this.

Calculation of aggregate market expenditures for each activity by income class began by multiplying per household expenditures on each activity for the income class by the number of households in the income class. This did not end the process, however, since there were also some households who did not report their income. Aggregate market expenditures by these families could, however, be calculated by multiplying their expenditures on each activity by the number of households not reporting their income. This amount was then distributed among income classes in proportion to expenditures by families reporting their income in each income class.

3. THE RESULTS

The empirical results of this study are shown in Appendix C. The first three columns for each income class show the average number of minutes per day devoted to each activity, while the fourth column shows the average market expenditures per household per year. Columns five through seven

give the aggregate value of time devoted to the activity by all employed men, employed women, and housewives in the income class, respectively. These figures were obtained by multiplying columns one through three by the corresponding population and wage rate. Column eight is simply the sum of columns five through seven. Column nine gives aggregate market expenditures by all households in the income class on the activity. Column 10 gives aggregate annual person-hours devoted to each activity, obtained by multiplying the figures in columns one through three by the corresponding population size, summing, and making necessary unit changes.

Continuing to the second page for each income class, column one gives the sum of columns eight and nine on the previous page--the total expenditures of time and money on each activity. Column two ranks the activities by total expenditures. Column three gives the market expenditures per person-hour spent on each activity. Hence, it represents the entries in column nine divided by the corresponding entries in column 10 on the previous page. Column four ranks the market expenditures per person-hour. Column five gives the ratio of value of time to total market expenditures. Hence, it represents the entries in column eight divided by the corresponding entries in column nine on the previous page. Column six ranks these ratios.

The third page for each income class shows the assumed population sizes and wage rates for the income class. The total number of employed males and females are based on 1973 averages as reported by the Bureau of Labor Statistics.[3] These populations were distributed among income classes in proportion to the aggregate number of person-hours worked, as estimated and Appendix B and shown in Table 9. The total number of housewives is based on the average number of women in 1973 not in the labor force due to the fact that they were "keeping house," as reported by the U.S. Bureau of Labor Statistics.[4] This total was distributed among income classes in proportion to the number of households in each income class, as shown in the _Consumer Expenditure Survey_. The total number of households is from the _Consumer Expenditure Survey_, with households not reporting their income being distributed among income classes in proportion to the number of households reporting an income in the class. Wage rates are as estimated in Appendix B.

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[3]U.S. Bureau of Labor Statistics, _Employment and Earnings_, U.S. Government Printing Office, January, 1974, p. 145.

[4]Ibid. p. 141.

4. CONCLUSIONS

The household economy far exceeds the market economy in size. If one were to redefine personal consumption expenditures (PCE) to include the value of time expended in the household, the 1973 Gross National Product (GNP) would have been around $4700 billion, rather than $1307 billion.[5] Many of the "industries" of the household economy are gigantic compared to most conventional industries. The value of time and money which are devoted to watching television, for example, far exceeds the market expenditures on either housing or food.

In virtually every activity, the value of time which people devote to the activity exceeds the value of market expenditures on the activity. This suggests a substantial willingness of people to pay for innovations which would reduce the time spent on activities which are displeasureable or neutral. Although this statement may not sound very original, this willingness to pay for time savings may be

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[5]This number was obtained by adding my total expense for all families (value of time and market expenditures) of $4197 billion to the 1973 total of $497 billion for gross private domestic investment, net exports, and government purchases. The number is approximate, since my definition of market expenditures does not exactly match the standard definition of PCE.

Source: U.S. Bureau of the Census, Statistical Abstract of the United States - 1978, p. 440.

much greater than is commonly perceived. For example, most of us are accustomed to thinking of eating out as an "expensive" activity. Yet, the data in Appendix C indicate that the value of a restaurant customer's time is an average of 1.9 times more valuable than the cost of the meal purchased. The success of the fast-food restaurant industry in recent years may be attributable more to the time savings these establishments offer than to their low prices. If this hypothesis is correct, there is every reason to expect that many people would prefer higher quality food than most fast-food restaurants offer, and be willing to pay for it, if only they could get it quickly. Hence, there is probably a substantial untapped market for high-quality fast-food restaurants.

In general, one might assume that the higher the ratio of time value to market expenditures, the more willing people would be to make a given percentage increase in their expenditures so as to obtain a given percentage decrease in time spent on an activity. House cleaning, with its 19.3 ratio, and personal care at home with a 25.7 ratio would seem ripe for innovation. So would education (2.3 ratio), reading (28.3), and hobbies and crafts (18.8). Although it would require a substantial technological breakthrough, any innovation which could safely and comfortably enable people to reduce the time they spend sleeping would have an enor-

mous impact. People currently spend time with a value roughly equal to the GNP sleeping.

For a few activities, expecially medical care and housing, the very low ratios of time value to market expenditure suggest that innovations which allow people to reduce market expenditures by devoting a bit more of their own time to the activity would have an impact. Do-it-yourself solar water heating systems might be one example of such an innovation. Various types of medical monitoring equipment for use in the home might be another.

Interestingly, the ratio of time value to market expenditures are remarkably stable across income classes. There are distinctly higher ratios for food and clothing in lower income classes, indicating a "do-it-yourself" tendency among lower income households. However, the opposite would appear to be true of housing. Perhaps this is because lower income households generally have more modest housing, requiring less care and maintenance than higher income households. As might be expected, market expenditures per hour devoted to an activity rise with income for all activities. In general, one might infer than all income classes would be receptive to innovations which improve household productivity.

There is a need for regular monitoring of the houshold economy through some indicators similar to those presently used to monitor the market economy. These indicators would not necessarily require the type of detailed time allocation data used in this study, although they could be improved if this type of data were available on a regular basis. Useful indicators of total household production could be developed from existing data on wage rates, employment, and the size of various socio-economic groups. These indicators would remind everyone of what has been demonstrated in this paper--that what most economic planners think of as 'the economy' is merely the tip of the economic iceberg. Hidden underneath are great opportunities for a better life.

Appendix A

DEVELOPING AN ACTIVITY CLASSIFICATION

Every effort was made to develop as detailed a classification of household activites as the data would allow. A 38-activity classification was ultimately developed. These are listed in Table 1, along with the time allocation study[6] activity classifications assigned to each one.

The 1972-73 Consumer Expenditure Survey, from which data on market expenditures were obtained, had two components. In the first, a sample of about 20,000 households[7] were asked to keep diaries of all their expenditures over a two week period. In the second, about 20,000 households were asked once each quarter for a year to report expenditures for "big ticket" items. The results of both survey compo-

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[6] John P. Robinson, How Americans Use Time: A Social-Psychological Analysis of Everyday Behavior, Praeger Publishers, New York, 1977;
and
John P. Robinson, How Americans Used Time in 1965, Institute for Social Research, University of Michigan, Ann Arbor, 1977. Available from University Microfilms, Ann Arbor, MI.

[7] A household is a group of persons, usually living together, who pool income and expenses, or a financially independent person.

TABLE 1

Assignment of Time Allocation Study Activities to Household Economy Study Activities

Household Economy Study Activity	Time Allocation Study Activity
Tradable Activities-	
1. Job	00 Normal Occupational Work Outside Home
	01 Normal Occupational Work at Home
	02 Overtime
	03 Travel During Work
	04 Waiting Time or Interruption During Work
	05 Second Job
	07 At Work, Other
	08 Work Breaks
2. Travel to Job	09 Travel to Job
3. Food Preparation	10 Food Preparation
	11 Meal Cleanup
	30 Shopping for Everyday Goods (57%)
	36 Waiting for Purchase of Goods and Services
	39 Travel Associated with Shopping (25%)
	49 Travel Associated with Personal Needs (25%)
4. Cleaning	12 Cleaning House
	13 Outdoor Chores
	30 Shopping for Everyday Goods (3%)
	39 Travel Associated With Shopping (2%)
	49 Travel Associated With Personal Needs (2%)
5. Gardening and Lawn Care	17 Gardening, Annimal

	Care (60%) 30 Shopping for Everyday Goods (1%) 39 Travel Associated With Shopping (1%) 49 Travel Associated With Personal Needs(1%)
6. Pet Care	17 Gardening, Animal Care (40%) 30 Shopping for Everyday Goods (1%) 39 Travel Associated with Shopping (1%) 49 Travel Associated with Personal Needs (1%)
7. Clothing and Linens	14 Laundry, Ironing 15 Clothes Upkeep 30 Shopping for Everyday Goods (13%) 35 Repair and CLeaning Services (60%) 39 Travel Associated with Shopping (14%) 49 Travel Associated with Personal Needs (14%)
8. House	16 Other Home Repairs 18 Upkeep of Heat and Water Supplies 31 Shopping for Durable Goods (90%) 39 Travel Associated with Shopping (20%) 49 Travel Associated with Personal Needs (20%)
9. Medical Care Given at Home	41 Personal Medical Care at Home (50%) 30 Shopping for Everyday Goods (1%) 39 Travel Associated with Shopping (1%) 49 Travel Associated with Personal Needs (1%)
10. Child Care	20 Baby Care 21 Child Care 22 Helping Child with Homework 27 Care of Other People's Children
11. Financial Management	19 Household Paperwork

	34 Government Services 37 Other Professional Services 39 Travel Associated with Shopping (20%) 49 Travel Associated with Personal Needs (20%)
12. Travel Associated with Professional Medical Care	39 Travel Associated with Shopping (2%) 49 Travel Associated with Personal Needs (2%)
13. Travel Associated with Education	59 Travel Associated with Education
14. Travel Associated with Organizations and Relgion	69 Travel Associated with Organizations and Religion
15. Travel Associated with Social Life and Entertainment	79 Travel Associated with Social Life and Entertainment
16. Travel Associated with Leisure Activities	89 Travel Associated with Leisure Activities
17. Shopping Associated with Non-Tradable Activities	10 Shopping for Everyday Goods (25%) 31 Shopping for Durable Goods (10%) 35 Repair and Cleaning Services (40%) 39 Travel Associated with Shopping (14%) 49 Travel Associated with Personal Needs (14%)

Non-Tradable Activities-

18. Personal Care at Home	40 Personal Hygiene 48 Other Private Activity
19. Personal Care Services	32 Personal Care Outside Home
20. Medical Care Received at Home	41 Personal Medical Care at Home (50%)
21. Professional Medical Care	33 Medical Care Outside Home
22. Eating at Home	43 Eating at Home

23. Eating Out	44 Meals Outside Home or Workplace 06 Meals at Work
24. Sleep and Rest	44 Essential Sleep 46 Incidental Sleep 47 Resting, Routine Naps 98 Relaxing
25. Vacation	See Text
26. Education	50 Attending Classes as Full-Time Student 51 Attending Classes as Part-Time Student 52 Attending Lectures or Special Talks 53 Political Programs or Union Training Class 54 Homework or Research 55 Reading Technical Journals or Books 56 Other Education
27. Religion	64. Participating in Religious Organizations 65 Religious Services
28. Other Organizations	60 Participating as Member of Social or Political Organization or Labor Union 61 Voluntary Activities as Elected Official of a Social or Political Organization or Labor Union 62 Participating in Meetings of Organizations 63 Unpaid Work for a Civic Purpose 64 Participating in Factory Council 67 Participating in Other Organizations 68 Other Organizational Activity
29. Television	91 Television
30. Reading	93 Reading Books 94 Reading Magazines 95 Reading Newspapers 99 Reading, Not Specified

31. Social Life	24 Indoor Play with Children 42 Care and Help Given to Other Adults 75 Entertaining or Visiting Friends 76 Parties or Receptions 77 Going to Bars, Tearooms, Soda Fountains, etc. 78 Other Social Life 87 Parlor Games
32. Conversation	23 Read or Talk with Children 96 Talking with Adults
33. Outdoors	25 Walking or Playing Outdoors with Children 80 Playing Sports or Physical Exercises 81 Hunting, Fishing, Camping, Pleasure Drives, Sightseeing 82 Talking a Walk or Hike
34. Entertainment	70 Attending Sports Events 71 Circuses, Fairs, Nightclubs, Dancing Parades 72 Attending Movies 73 Attending Theater, Concerts or Opera 74 Attending Museums, Exhibitions, or Galleries
35. Listening to Sounds	19 Listening to Records or Tape Recording 22. Listening to Radio
36. Performing	86 Playing a Musical Instrument, Singing, Artistic Dancing
37. Hobbies and Crafts	83 Hobbies and Collections 84 Women's Home Crafts 85 Artistic Hobbies 88 Other Leisure
38. Personal Letters	97 Writing Private Correspondence

nents have been compiled as an integrated set of tables.[8] However, a greater level of commodity detail is provided in the separate publications on each segment of the survey.[9] Both surveys were done over a two-year period, with no adjustments made for price changes over that time. Hence, the expenditures shown may be viewed as averages of expenditures over this period. The diary survey began six-months later than the interview survey, with price level adjustments being made to ensure that the integrated diary and interview survey data reflected calendar years 1972-73. Data are presented according to various socio-economic breakdowns, including 12 household income levels and seven occupational groups.

Table 2 shows the consumer expenditure classes assigned to each household activity. Whenever possible, the classes come from among those used in the integerated diary and interview survey data. In some cases, these classes did not provide sufficient detail for this study. The separate diary and interview survey publications provided a more de-

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[8]U.S. Bureau of Labor Statistics, Consumer Expenditure Survey: Integrated Diary and Interview Survey Data, 1972-73, Bulletin 1992, U.S. Government Printing Office, Washington, DC, 1978.

[9]U.S. Bureau of Labor Statistics, Consumer Expenditure Survey: Diary Survey, July 1972-June 1974, Bulletin 1959, U.S. Government Printing Office, Washington, DC, 1977;
and
U.S. Bureau of Labor Statistics, Consumer Expenditure Survey: Interview Survey, 1972-73, Bulletin 1997, U.S. Government Printing Office, Washington, DC, 1978.

tailed breakdown of many of these classes, which were used where necessary. Where data was taken from one of the separate survey publications, this is indicated by a footnote in Table 2.

With three exceptions, expenditures reported from the broad classes shown in the integrated diary and interview survey publication equaled the sum of the corresponding more detailed expenditure classes in the interview survey publication, where the data from the interview survey was used in this study. Thus, this detailed expenditure data from the interview survey publication was directly comparable to the expenditure data reported in the integrated publication, and could be used without modification. In three exceptional cases small adjustments were made, as explained in the footnotes to Table 2, to insure comparability of this data.

Expenditure data for the classes in the integrated publication never exactly equal the sum of the expenditures shown for the corresponding more detailed classes in the diary survey publication, due to price level adjustments made to this data in the integration process by the Bureau of Labor Statistics. These adjustments were made due to the fact that the diary survey actually began six months after the interview survey, as explained above. Where diary survey data were used, expenditures shown in the diary survey were

TABLE 2

Assignment of Consumer Expenditure Classes to Household Economy Study Activities

Household Economy Study Activity	Consumer Expenditure Survey Class
Tradable Activities-	
1. Job	
2. Travel to Job	Transportation (35.4%)
3. Food Preparation	Food at Home (98%) Refrigerators and Freezers (1) Cooking Ranges (1) Dishwashers and Garbage Disposals (1) Toasters, Coffeemakers, Blenders (1) Range Hoods and Electric Kitchen Equipment (1) Domestic Services- Domestic and Other Duties (50%) (2) Housewares Miscellaneous Household Products (50%)(3) Service Contracts on Appliances (50%)(4) Transportation (8.7%)
4. Cleaning	Cleaning Supplies (3) Vaccuums and Other Electric Floor Equipment (1) Domestic Services- Domestic and Other Duties (50%)(2) Transportation (.5%)
5. Gardening and Lawn Care	Gardening and Lawn Care Services (2) Fertilizers and Pesticides (2) Lawn and Garden Supplies (3) Lawnmowers (4) Transportation (.3%)
6. Pets and Animals	Pet Purchases, Supplies, and Other (1) Pets, Toys, and Games (10%) Food at Home (2%)

	Transportation (.3%)
7. Clothing and Linens	Laundry Supplies (3) Clothing Purchases Dry CLeaning and Laundry Washing Machines (1) Clothes Dryers (1) Sewing Machines (1) Household Textiles Paper Towels, Napkins and Tissues (66%)(3) Service Contracts on Appliances (50%)(4) Transportation (6%)
8. House	Shelter Other Household Repairs (2) Reupholstering and Furniture Repair (2) Appliance Repair and Servicing (2) Moving, Freight, and Storage Charges (2) Fuel and Utilities Furniture Floor Coverings Heaters, Fans, Humidifiers, Vaporizers (1) Miscellaneous Items (2) Dehumidifiers, Air Conditioners (1) Miscellaneous Household Products (50%)(3) Lamps, Chandeliers, and Other Fixtures (4) Window Shades, Blinds, and Rods (4) Clocks, Mirrors and Decorative Items (4) Hand and Power Tools (4) Insurance on Personal Effects (4) Other Household Expenses (1) Transportation (2.5%)
9. Medical Care Given at Home	Nonprescription Drugs and Medical Supplies Domestic Services-Child Care and Care for Elderly (50%)(2) Transportation (5.4%)
10. Child Care	Toys (1) Pets, Toys and Games (45%)

	Domestic Services- Child Care and Care for the Elderly (50%)(2) Transportation (5.4%)
11. Financial Management	Stationary and Greeting Cards (50%)(3) Personal Insurance, Retirement and Pensions Miscellaneous Typewriters and Home Use Office Equipment Transportation (5.2%)
12 Travel Associated with Professional Medical Care	Transportation (2%)
13. Travel Associated with Education	Transportation(1%)
14. Travel Associated with Organizations and Religion	Transportation (5.3%)
15. Travel Associated with Social Life and Entertainment	Transportation (15.6%)
16. Travel Associated with Leisure Activities	Transportation (2.7%)
17. Shopping Associated with Non-Tradable Activities	Transportation (8.6%)

Non-Tradable Activities-

18. Personal Care at Home	Personal Care Products (5) Paper Towels, Napkins, and Tissues (3)
19. Personal Care Outside Home	Personal Care Services (5)
20 Medical Care Received at Home	
21. Professional Medical Care	Health Care Expenses Not Covered by Insurance Health Insurance
22. Eating at Home	

23. Eating Out	Food Away from Home Meals as Pay
24. Sleep and Rest	
25. Vacation	Vacation and Pleasure Trips Owned Vacation Home Luggage, Footlockers, and Trunks (4)
26. Education	Education
27. Religion	Gifts to Religious Organizations (6)
28. Other Organizations	Gifts to Welfare Organizations (6) Gifts to Educational, Political, and Other Organizations (6)
29. Television	Television Television Cable Services (1) TV, Radio, Musical Instrument, and Other Repairs and Rentals (60%)(1)
30. Reading	Reading
31. Social Life	Pets, Toys, and Games (45%) Gifts to Individuals Outside Family (6) Alchoholic Beverages Tobacco Products and Smoking Supplies
32. Conversation	Telephone
33. Outdoors	Boats, Aircraft and Wheel Goods Club and Membership Dues (1) Bicycles, Tricycles, and Powered Carts (1) Sports Equipment (1) Playground, Camping, and Other Equipment (1)
34. Entertainment	Season Tickets, Admissions, and Fees (1)
35. Listening to Sounds	Radios (1) Phonographs, Tape Recorders, and Other (1) Component Systems, Parts and Other (1)

	Records, Reels, and Cassetts (1) TV, Radio, Musical Instrument, and Other Repairs and Rentals (40%) (1)
36. Performing	Musical Instruments and Accessories (1) Lessons (40%)(1)
37. Hobbies and Crafts	Photography (1) Lessons (40%)(1)
38. Personal Letters	Stationary and Greeting Cards (50%)(3)

(1) Taken from interview survey publication.

(2) The integrated diary and interview survey publication gives one figure for "Domestic and Other Household Services", which includes the following classifications from the interview survey publication:

Domestic Services-Domestic and Other Duties
Domestic Services-Child Care and Care for Elderly
Gardening and Lawn Care Services
Other Household Repairs
Reupholstering and Furniture Repair
Appliance Repair and Servicing
Moving, Freight, and Storage Charges
Fertilizers and Pesticides

However, these classifications do not sum to match the total shown in the integrated publication. The difference is evidently due to the inclusion of a few miscellaneous items from the diary survey, including locksmith services, small houseplants, seeds, and bulbs. This was resolved by using the figures for the above classifications shown in the interview survey publication, and creating a new classification "Miscellaneous Items" for the difference between the total expenditures for the above classifications and the total expenditures shown in the integrated publication.

(3) These classifications were lumped together under the heading of "Housekeeping and Laundry Supplies" in the integrated diary and interview survey publication. Detailed expenditure data was taken from the diary survey publication, and scaled to make the total of all these classifications match the total shown in the integrated publication.

(4) The integrated diary and interview survey publication gives one figure for "Miscellaneous Household Expense", which includes these classifications from the interview survey publication. However, expenditures on these classifications do not match the total shown in the integrated publication. The difference is evidently due to the inclusion of expenditures on sheds from the diary

survey. This was resolved by adding the difference between the total of these classifications shown in the interview survey publication and the total shown in the integrated publication to the figure for "Other Household Expenses." Expenditures on other classifications were taken directly from the interview survey publication.

(5) These classifications were lumped together under the heading of "Personal Care" in the integrated diary and interview survey publication. Detailed expenditure data was taken from the diary survey publication, and scaled to make the total of all these classifications match the total shown in the integrated publication.

(6) The integrated diary and interview survey publication gives one figure for "Gifts and Contributions", which includes these classifications from the interview survey publication. However, expenditures on these classifications do not sum to match the total shown in the integrated publication. The difference is evidently due to the inclusion of some small contributions from the diary survey. This was resolved by scaling the detailed expenditure data to make the total of all these classifications match the total shown in the integrated publication.

scaled by the factor necessary to ensure that the expenditure shown for a class in the integrated publication equaled the sum of the corresponding expenditures in the diary survey publication.

The most troublesome group of activities to deal with in developing this classification were those related to travel. They will be regarded as tradable, since even though it is not possible to pay someone else to do one's own traveling, it is generally possible to pay to have whatever one is traveling to brought to one's home. For example, if one does not wish to travel to school, one could hire a tutor to give lessons at home. In this sense, travel competes directly with services offered in the market economy.

With the exception of "Travel to Job", the time and expense of travel associated with tradable activities (numbers 3-11) were included in the times and expenses of these activities. "Travel to Job" was felt to be so important that it was made a separate activity. Since travel was considered to be a tradable activity, it seemed inappropriate to include the time and expense of travel associated with non-tradable activities in the times and expenses allocated to these activities. Hence, five special tradable activities were created for them (numbers 12-16).

Travel while on vacation was considered to be different from other types of travel associated with non-tradable activities, since one cannot generally pay to have the vacationland brought to one's home. Furthermore, vacation travel may be an integral part of the activity of vacationing, not simply something which must be done in order to carry out some other activity, as is usually the case for travel associated with other activities. Hence, the time and expense of vacation travel was included in the activity "vacation".

Shopping is similarly a tradable activity, which is associated with most activities, both tradable and non-tradable. The time spent on shopping associated with activities 2-16 were included in the time of these activities, while the time spent on shopping associated with non-tradable activities 18-38 were made into a separate activity "Shopping Associated With Non-Tradable Activities."

Unfortunately, the time allocation study does not break down time spent traveling and shopping into this much detail. While travel activites 13-16 are broken out, as well as travel to job and travel associated with child care, all other travel in the time allocation study is lumpted together under "Travel Associated with Purchasing Goods and Services" and "Travel Associated with Personal Needs".

Shopping is broken down into only "Shopping for Everyday Goods", "Shopping for Durable Goods", and "Waiting for Purchase of Goods and Services." There is very little published data which could be used to further breakdown these classifications. Even if data on time allocations by detailed purpose of trip had been collected, it would be difficult to analyze, since consumers so frequently do several types of shopping and errands on a single trip. A Federal Highway Administration study provides some very limited guidance.[10] The sum total of the time allocations for "Travel Associated with Purchasing Goods and Services" and "Travel Associated with Personal Needs" were allocated among activities based on estimates made by the author. Similarly, the time allocations for shopping were allocated among activities based on estimates made by the author. The percentage of the total allocated to each activity is indicated in Table 1.

Except for transportation expenditures while on vacation, the consumer expenditure survey provides no breakdown of transportation expenses by purpose of trip. Transportation expenses were therefore distributed among activities in pro-

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[10] U.S. Federal Highway Administration, Nationwide Personal Transportation Study; Report no. 10: Purposes of Automobile Trips and Travel, Washington, DC, May, 1974. Additional data from this study is presented in U.S. Department of Transportation, 1974 National Transportation Report, Washington, DC, July, 1975, pp. 133-134.

portion to a weighted average of the travel times of employed men, employed women, and housewives allocated to each activity. The percentage of total non-vacation transportation expense allocated to each activity is indicated in Table 2.

The time allocation study did not survey people who were on overnight trips, hence most vacation time was excluded. In order to estimate time spent vacationing, it is necessary to turn to the Census of Transportation. The average trip duration is estimated from the following distribution of trip durations:[11]

Duration	1967 Total Person-Trips (millions)	Percent Non-Business
1 Day	31.5	73.6
1 Night	89.7	84.2
2 Nights	94.1	88.6
3 to 5 Nights	75.7	84.9
6 to 9 Nights	34.8	92.5
10 to 15 Nights	20.3	92.2
>16 Nights	15.1	89.3

One day trips will be ignored, as presumably they were included in the time allocation survey under one of the leisure activities. It will be assumed that one night trips lasted an average of 24 hours; two night trips lasted an average of 48 hours; three to five night trips lasted an aver-

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[11]U.S. Bureau of the Census, 1967 Census of Transportation; Volume I, National Travel Survey, Washington, DC, July, 1970, p. 24.

age of 96 hours; six to nine night trips lasted an average of 180 hours; ten to fifteen night trips lasted an average of 300 hours; and sixteen nights or more trips lasted an average of 480 hours. Using the number of non-business trips as a weighting factor, an average trip duration of 104 hours may be obtained.

The Census of Transportation also provides data on the number of trips by household income level. From this, the average annual number of non-business overnight trips per person by income level may be calculated (see Table 3). Multiplying this average number of trips by average trip duration of 104 hours gives the following annual number of hours per person spent on overnight vacation trips by income class:

Household Income Level (1967)	Average Annual Number of Hours Spent on Overnight Vacation Trips Per Person
<$4000	98
$4,000-$5,999	185
$6,000-7,499	205
$7,500-9,999	168
$10,000-14,999	140
$15,000	131
All	151

Estimated average number of minutes per day spent on the activity "vacation" were obtained by simply converting these figures into units of minutes per day. The time spend on all other activities were scaled down to ensure than the sum of all daily activities equaled 1440 minutes (24 hours).

TABLE 3

Calculation of the Annual Number of Non-Business Trips Per Person

Household Income Level	1967 Number of Trips(1)	Percent Non-Business	Estimated Population(2)	Average Annual Non-Business Trips Per Person
<$4,000	38.5	91.5	37.4	.94
$4,000-5,999	52.4	92.5	27.3	1.78
$6,000-$7,499	53.5	90.4	24.5	1.97
$7,500-9,999	70.6	88.0	38.3	1.62
$10,000-14,999	73.4	80.7	43.9	1.35
>$15,000	41.3	74.0	24.3	1.26
Total	329.7	86.0	195.8	1.45

1) The number of trips for each family income level was scaled to give a total of 329.7 million trips, the number of trips of one night or more duration recorded above.

2) Source: U.S. Bureau of the Census, Current Population Reports, Series P-60, No. 59, "Money Income in 1967 of Families," U.S. Government Printing Office, Washington, DC, April, 1969, pp. 39,41. Represents sum of families and unrelated individuals. The Census Bureau's $7,000-7,999 income class was divided evenly between the $6,000-$7,499 and $7,500-9,999 income classes.

Appendix B

ESTIMATION OF AVERAGE WAGE RATES BY HOUSEHOLD INCOME CLASS

Average wage rates by household income class may be obtained by estimating aggregate earnings[12] after taxes by all persons in an income class, and dividing this by an estimate of the aggregate number of person-hours worked by individuals in the income class. Aggregate earnings for an income class may be estimated by multiplying average earnings of each household in an income class by the total number of households in the income class. Both sets of data are given by the Consumer Expenditure Survey. Aggregate earnings may then be multiplied by one minus the tax rate to give aggregate earnings by families after taxes (see Table 4). The Consumer Expenditure Survey shows taxes paid by each type of tax, hence the tax rate may be easily calculated. The tax rate includes federal, state, and local income taxes. Although it would be appropriate to include Social Security taxes in the tax rate as well, the Consumer Expenditure Survey includes Social Security taxes in the "Health Insurance"

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[12]As used in this report, "earnings" refers only to wages, salaries, and self-employment income, while "income" includes transfer payments, such as social security and welfare, and property income, such as rents and dividends.

and "Personal Insurance, Retirement, and Pensions" categories. It is unfortunately not possible to recover the cost of Social Security taxes from this data. After-tax wages will be used in this study, since the after-tax wage is the value of time as perceived by the individual involved.

TABLE 4

Aggregate Annual Earnings by Income Class

Household Income Class	Number of Households(1) (Millions)	Earnings Per Household ($)	Aggregate Earnings (Mil-ion$)	Tax Rate	Aggregate Earnings After Tax (Mil-lion $)
<$3,000	9.572	292.48	2799.6	3.8%	2693.2
$3,000-3,999	4.214	1198.56	5050.7	3.6%	4868.9
$4,000-4,999	3.827	2115.49	8095.0	4.9%	7699.3
$5,000-5,999	3.466	3006.97	10422.2	6.7%	9723.9
$6,000-6,999	3.591	4120.37	14796.2	7.9%	13,627.3
$7,000-7,999	3.43	5350.16	18351.0	9.7%	16,571.0
$8,000-9,999	6.963	7018.49	48,870.0	11.2%	43,396.3
$10,000-11,999	6.629	9422.01	62,458.5	12.9%	54,501.4
$12,000-14,999	8.844	11,784.39	104,221.1	14.0%	89,630.2
$15,000-19,999	10.555	15,504.39	163,648.1	15.2%	138,774.2
$20,000-24,999	5.309	20,211.54	107,303.1	16.6%	89,490.8
>$25,000	4.815	32,654.29	157,230.4	18.6%	127,985.6

(1) 3.773 million households who did not report their income were distributed over income classes in proportion to the number of households reporting an income in each class.

Source: U.S. Bureau of Labor Statistics, Consumer Expenditure Survey: Integrated Diary and Interview Survey Data, Bulletin 1992, U.S. Government Printing Office, Washinton, DC, 1978, pp. 24-35.

Calculation of the aggregate number of person-hours worked by income class is a bit more difficult. Beginning with the year 1975, the Census Bureau began publishing data on the number of full-time year-round earners[13] per family by income class. Thus, one can estimate the number of full-time year-round earners in families simply by multiplying the number of families by the number of full-time year-round earners (see Table 5).

The Census Bureau, however, defines a family as two or more persons related by blood, marriage, or adoption living together. Since this study is concerned with all households, including those consisting of only one person, it is necessary to add the number of full-time year-round earners among what the Census Bureau calls "unrelated individuals." Fortunately, data has also been published on this (see Table 6). The result is the number of full-time year-round earners in each income class.

The total number of full-time earners may be estimated from these figures by assuming the number of full-time earners in each income class is proportional to the number of full-time year-round earners. Thus, the total number of full-time earners is distributed among income classes in

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[13]A "year-round" earner is someone who was employed 50 or more weeks in the previous year.

TABLE 5

Number of Full-Time Year-Round Earners in Families

Household Income Class	Number of Families(1) (000)	Full-Time Year-Round Earners Per Family(2)	Family Full-Time Year-Round Earners (000)
<$1,000	605.58	.22	133.23
$1,000-1,499	385.37	.22	84.78
$1,500-1,999	605.58	.22	133.23
$2,000-2,499	770.74	.11	84.78
$2,500-2,999	935.90	.11	102.95
$3,000-3,499	1101.06	.10	110.11
$3,500-4,000	1156.11	.10	115.61
$4,000-4,999	2477.39	.17	421.16
$5,000-5,999	2532.44	.26	658.43
$6,000-6,999	2642.54	.34	898.46
$7,000-7,999	2697.60	.46	1240.90
$8,000-8,999	2807.70	.53	1488.08
$9,00-9,999	2697.60	.64	1726.46
$10,000-11,999	5890.67	.75	4418.00
$12,000-14,999	8147.84	.92	7496.01
$15,000-24,999	14,478.94	1.19	17,229.94
$25,000-$49,999	4569.40	1.47	6717.02
>$50,000	550.53	1.16	638.61

(1) Source: U.S. Bureau of the Census, Current Population Reports, Series P-60, No. 97, "Money Income in 1973 of Families and Persons in the United States", U.S. Government Printing Office, Washington, DC, 1975, p. 46.

(2) Source: U.S. Bureau of the Census, Current Population Reports, Series P-60, No. 105, "Money Income in 1975 of Families and Persons in the United States", U.S. Government Printing Office, Washington, DC, 1977, p. 112.

proportion to the number of full-time year-round earners. In a similar fashion, the number of part-time earners in each income range may be obtained by distributing the total number of part-time earners over the income ranges in proportion to the number of full-time year-round earners in

TABLE 6

Number of Full-Time Year-Round Earners Among Unrelated Individuals

Household Income Class	Number of Unrelated Indiv-iduals(1) (000)	Full-Time Year-Round Earners Per Unrelated Indiv-idual(2)	Unrelated Individual Full-Time Year-Round Earners (000)
<$1000	1387.76	.082	113.80
$1,000-1,499	1168.64	.040	46.75
$1,500-1,999	1442.54	.024	34.62
$2,000-2,499	1679.92	.029	48.72
$2,500-2,999	1278.20	.030	38.35
$3,000-3,499	1095.60	.059	64.64
$3,500-3,999	858.22	.105	90.11
$4,000-4,999	1698.18	.192	326.05
$5,000-5,999	1296.46	.300	388.94
$6,000-6,999	1040.82	.435	452.76
$7,000-7,999	931.26	.498	463.77
$8,000-8,999	858.22	.574	492.62
$9,000-9,999	675.62	.626	422.94
$10,000-11,999	1004.30	.706	709.04
$12,000-14,999	913.00	.749	683.84
$15,000-24,999	766.92	.792	607.40
$25,000-49,999	127.82	.812	103.79
>50,000	54.78	.711	38.95

(1) Source: U.S. Bureau of the Census, Current Population Reports, Series P-60, No. 97, U.S. Government Printing Office, Washington, DC, 1975, p. 47.

(2) Source: U.S. Bureau of the Census, Current Population Reports, Series P-60, No. 105, U.S. Government Printing Office, Washington, DC, 1977, p. 155

each range (see Table 7). The total number of person-hours worked may be obtained by assuming each full-time earner works 40 hours a week 52 weeks a year, while each part-time earner works 20 hours a week 52 weeks a year.

TABLE 7

Aggregate Person-Hours Worked

Household Income Class	Total Full-Time Year Round Earners (000)	Total Estimated Full-Time Earners (000)	Total Estimated Part-Time Earners (000)	Total Annual Person Hours Worked(2) (Millions)
<$1,000	247.0	354.4	72.6	812.6
$1,000-1,499	131.5	188.7	38.7	433.2
$1,500-1,999	167.9	240.9	49.4	552.4
$2,000-2,499	133.5	191.5	39.3	439.2
$2,500-2,999	141.3	202.7	41.6	464.9
$3,000-3,499	174.8	250.8	51.4	575.1
$3,500-3,999	205.7	295.1	60.5	676.7
$4,000-4,999	747.2	1072.1	219.7	2458.5
$5,000-5,999	1047.4	1502.8	308.0	3446.1
$6,000-6,999	1351.2	1938.6	397.3	4445.5
$7,000-7,999	1704.7	2445.8	501.3	5608.6
$8,000-8,999	1980.7	2841.8	582.5	6516.7
$9,000-9,999	2149.4	3083.9	632.1	7071.9
$10,000-11,999	5127.0	7356.0	1507.7	16,868.5
$12,000-14,999	8179.9	11,736.2	2405.5	26,913.0
$15,000-24,999	17,837.3	25,592.2	5245.4	58,687.0
$25,000-49,999	6820.8	9786.2	2005.8	22,441.3
>50,000	677.6	972.2	199.3	2229.4

(1) Source: Total number of full-time and part-time employed persons from U.S. Bureau of Labor Statistics, Employment and Earnings, U.S. Government Printing Office, Washington, DC, January, 1974, p. 145. Figures based on annual averages for 1973.

(2) See text.

This procedure probably tends to understate the number of employees in the lower income ranges, where people probably work on a more intermitent basis, but it seems to be about the best which can be done with available data. 1973 Census data will be used throughout to ensure comparability with

the Consumer Expenditure Survey, except for the number of full-time year-round earners per family by income class, which will be for 1975, the first year it was published.

Before proceeding to divide aggregate earnings by hours worked, it is necessary to reconcile the income classes used in the various data sources. Since the income classes given for the time allocation study are for the year 1965, they must be adjusted for inflation to make them comprable to the remaining data, which is for the year 1973. One 1965 dollar had the purchasing power of 1.4 1973 dollars, according to the consumer price index. Table 8 shows the household economy study income classes used here, and the corresponding income classes in the data sources. It was necessary to split the Census Bureau's $15,000-25,000 income class between the $12,000-19,999 and >$20,000 classes used here. This was done by dividing the earnings in the $15,000-$25,000 income class between the two classes in proportion to the number of households in the two classes, as reported in the <u>Consumer Expenditure Survey</u>.

Table 9 shows the average after-tax wage rates which result from dividing aggregate earnings by aggregate person-hours worked. There are, however, significant differences in earnings between the sexes. The average full-time year-round male earner earned 1.158 times as much as the average

TABLE 8

Correspondence of Income Classes

Household Economy Study Income Class (1973 $)	Time Allocation Study Income Class (1965 $)	Census Bureau Income Class (1973 $)	Consumer Expenditure Study Income Class (1973 $)
<$5,000	<$4,000	<$1,000	<$3,000
		$1,000-1,499	$3,000-3,999
		$1,500-1,999	$4,000-4,999
		$2,000-2,499	
		$2,500-2,999	
		$3,000-3,499	
		$3,500-3,999	
		$4,000-4,999	
$5,000-7,999	$4,000-5,999	$5,000-5,999	$5,000-5,999
		$6,000-6,999	$6,000-6,999
		$7,000-7,999	$7,000-7,999
$8,000-9,999	$6,000-7,499	$8,000-8,999	$8,000-9,999
		$9,000-9,999	
$10,000-11,999	$7,500-9,999	$10,000-11,999	$10,000-11,999
$12,000-19,999	$10,000-14,999	$12,000-14,999	$12,000-14,999
		$15,000-25,000*	$15,000-19,999
>$20,000	>15,000	$15,000-25,000*	$20,000-24,999
		>25,000	$25,000-49,999
			>$50,000

*Number of earners in $15,000-25,000 income class allocated between $12,000-19,999 and >$20,000 household economy study income classes in proportion to the number of families in each class, as reported in the <u>Consumer Expenditure Survey</u>.

full-time year-round earner, while the average full-time year-round female earner earned only .637 times as much as the average full-time year-round earner.[14] It will be assumed that these same ratios apply to all types of earners at all income levels.

TABLE 9

Average Wage Rates

Household Economy Study Income Class	Aggregate Earnings (Million $)	Aggregate Person-Hours Worked (Millions)	Hourly Wage (After Tax $)
<$5,000	15,261.4	6412.6	2.38
$5,000-7,999	39,922.2	13,500.2	2.96
$8,000-9,999	43,396.3	13,588.6	3.19
$10,000-11,999	54,401.4	16,868.5	3.23
$12,000-19,999	228,404.4	65,959.5	3.46
>$20,000	217,476.4	44,311.2	4.91
Total	598,862.1	160,640.5	3.73

The before-tax wage rate for housewives was assumed equal to the average earnings of a full-time year-round female earner in 1973 of $6661 per year[15] or $3.20 per hour. The after-tax wage rate for housewives was calculated for each income class by multiplying this by one minus the tax rate for the income class. The tax rates are a weighted average of those shown in Table 4, where the weighting is by number of households.

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[14] U.S. Bureau of the Census, Current Population Reports, Series P-60, No. 97, U.S. Government Printing Office, Washington, DC, 1975, pp. 137-139.

[15] U.S. Bureau of the Census, Current Population Reports, Series P-60, No. 97, "Money Income in 1973 of Families and Persons in the United States", U.S. Government Printing Office, 1975, p. 139.

APPENDIX C

VALUE OF TIME VS. MARKET EXPENDITURES
BY INCOME CLASSES

VALUE OF TIME VS. MARKET EXPENDITURES FOR THE UNDER $5000 HOUSEHOLD INCOME CLASS

		MINUTES/DAY			1973 $/HOUSEHOLD MARKET EXPENDITURES	BILLION 1973 $					
	ACTIVITY	EMPLOYED MEN	EMPLOYED WOMEN	HOUSEWIVES		EMPLOYED MEN VALUE OF TIME	EMPLOYED WOMEN VALUE OF TIME	HOUSEWIVES VALUE OF TIME	TOTAL VALUE OF TIME	TOTAL MARKET EXPENDITURES	PERSON HOURS (MILLIONS)
1	JOB	426.75	303.76	9.95	0.0	14.84	3.63	1.62	20.09	0.00	8292.8
2	TRAVEL TO JOB	34.16	32.57	1.28	194.1	1.19	0.39	0.21	1.79	3.42	754.5
3	FOOD PREPARATION	29.09	79.46	160.09	756.0	1.01	0.95	26.04	28.00	13.31	9473.8
4	HOUSE CLEANING	7.01	38.88	72.49	28.1	0.24	0.46	11.79	12.50	0.49	4234.9
5	GARDENING	1.49	1.24	2.35	24.7	0.05	0.01	0.38	0.45	0.43	152.8
6	PET CARE	1.11	0.93	1.71	28.2	0.04	0.01	0.28	0.33	0.50	111.8
7	CLOTHING AND LINENS	6.41	26.22	51.69	326.7	0.22	0.31	8.41	8.94	5.75	3025.8
8	HOUSE	12.37	5.21	9.05	1150.9	0.43	0.06	1.47	1.96	20.27	676.3
9	MEDICAL CARE GIVEN	0.58	0.56	0.79	44.9	0.02	0.01	0.13	0.16	0.79	53.5
10	CHILD CARE	3.72	25.75	99.99	49.7	0.13	0.31	16.26	16.70	0.87	5547.4
11	FINANCIAL MANAGEMENT	21.88	24.28	22.54	163.1	0.76	0.29	3.67	4.72	2.87	1660.8
12	TRAVEL/PRO MEDICAL	0.51	0.39	0.48	11.0	0.02	0.00	0.08	0.10	0.19	35.1
13	TRAVEL/EDUCATION	0.84	0.41	0.51	5.5	0.03	0.00	0.08	0.12	0.10	40.9
14	TRAVEL/ORG & RELIGION	3.37	2.47	2.55	29.1	0.12	0.03	0.41	0.56	0.51	197.0
15	TRAVEL/SOCAL LIFE	10.12	8.23	6.63	85.5	0.35	0.10	1.08	1.53	1.51	543.4
16	TRAVEL/LEISURE	1.69	1.65	1.02	14.8	0.06	0.02	0.17	0.24	0.26	88.2
17	SHOPPING/NON-TRADABLE	7.23	6.69	8.33	47.2	0.25	0.08	1.35	1.69	0.83	585.0
	TOTAL--TRADABLE	568.33	558.69	451.43	2959.3	19.76	6.68	73.43	99.87	52.11	35474.0
18	PERSONAL CARE @HOME	52.14	75.18	49.28	36.7	1.81	0.90	8.02	10.73	0.65	3859.3
19	PERSONAL CARE SERVICES	0.91	2.03	1.43	42.7	0.03	0.02	0.23	0.29	0.75	103.2
20	MED CARE RECEIVE @HOME	0.23	0.25	0.36	0.0	0.01	0.00	0.06	0.07	0.00	23.8
21	PRO MEDICAL CARE	0.91	1.02	1.43	247.3	0.03	0.01	0.23	0.28	4.35	95.2
22	EATING AT HOME	58.77	43.71	48.94	0.0	2.04	0.52	7.96	10.53	0.00	3677.3
23	EATING OUT	32.99	21.85	4.14	160.8	1.15	0.26	0.67	2.08	2.83	806.7
24	SLEEP AND REST	467.04	468.18	536.31	0.0	16.24	5.60	87.24	109.08	0.00	37983.6
25	VACATION	16.20	16.13	16.21	72.1	0.56	0.19	2.64	3.39	1.27	1189.8
26	EDUCATION	19.63	12.03	0.00	15.0	0.68	0.14	0.00	0.83	0.26	342.0
27	RELIGION	3.22	12.68	12.79	53.9	0.11	0.15	2.08	2.34	0.95	818.1
28	OTHER ORGANIZATIONS	0.00	9.47	0.43	15.1	0.00	0.11	0.07	0.18	0.27	97.2
29	TELEVISION	81.67	94.59	151.70	30.5	2.84	1.13	24.68	28.65	0.54	9810.9
30	READING	25.86	22.30	15.97	19.1	0.90	0.27	2.60	3.76	0.34	1347.6
31	SOCIAL LIFE	48.59	50.35	94.37	221.9	1.69	0.60	15.35	17.64	3.91	6008.7
32	CONVERSATION	22.86	19.68	33.98	107.2	0.79	0.24	5.53	6.56	1.89	2243.2
33	OUTDOORS	12.00	0.70	8.52	21.8	0.42	0.01	1.39	1.81	0.38	608.4
34	ENTERTAINENT	15.53	17.27	0.00	13.1	0.54	0.21	0.00	0.75	0.23	331.4
35	LISTENING TO SOUNDS	11.04	4.78	4.47	26.3	0.38	0.06	0.73	1.17	0.46	413.4
36	PERFORMING	0.22	0.28	0.56	3.2	0.01	0.00	0.09	0.10	0.06	34.5
37	HOBBIES AND CRAFTS	1.20	5.52	4.89	8.4	0.04	0.07	0.80	0.90	0.15	317.7
38	PERSONAL LETTERS	0.66	3.31	2.79	4.3	0.02	0.04	0.45	0.52	0.08	182.4
	TOTAL	1440.00	1440.00	1440.00	4058.7	50.07	17.22	234.24	301.53	71.47	105767.8

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CONTINUATION OF VALUE OF TIME VS. MARKET EXPENDITURES FOR THE UNDER $5000 HOUSEHOLD INCOME CLASS

		TOTAL EXPENSE BILLION $	RANK	MARKET EXPENDITURES PER HOUR	RANK	RATIO TIME VALUE/ MARKET EXPENDITURES	RANK
1	JOB	20.0889	6	0.0000	--	-----	--
2	TRAVEL TO JOB	5.2041	14	4.5301	6	0.5225	30
3	FOOD PREPARATION	41.3153	2	1.4052	19	2.1034	16
4	HOUSE CLEANING	12.9937	9	0.1166	33	25.3034	2
5	GARDENING	0.8831	30	2.8445	10	1.0312	23
6	PET CARE	0.8243	31	4.4425	7	0.6596	28
7	CLOTHING AND LINENS	14.6975	8	1.9013	15	1.5548	20
8	HOUSE	22.2319	4	29.9685	2	0.0969	33
9	MEDICAL CARE GIVEN	0.9451	29	14.7583	3	0.1965	32
10	CHILD CARE	17.5764	7	0.1576	32	19.0985	3
11	FINANCIAL MANAGEMENT	7.5902	13	1.7299	16	1.6419	19
12	TRAVEL/PRO MEDICAL	0.2942	35	5.5035	5	0.5230	29
13	TRAVEL/EDUCATION	0.2137	36	2.3620	14	1.2136	21
14	TRAVEL/ORG & RELIGION	1.0731	25	2.5981	13	1.0970	22
15	TRAVEL/SOCAL LIFE	3.0343	20	2.7718	11	1.0147	24
16	TRAVEL/LEISURE	0.5049	33	2.9555	9	0.9365	25
17	SHOPPING/NON-TRADABLE	2.5164	21	1.4195	18	2.0305	17
	TOTAL--TRADABLE	151.9869		1.4690		1.9165	
18	PERSONAL CARE @HOME	11.3747	10	0.1677	31	16.5773	4
19	PERSONAL CARE SERVICES	1.0412	27	7.2951	4	0.3832	31
20	MED CARE RECEIVE @HOME	0.0691	38	0.0000	--	-----	--
21	PRO MEDICAL CARE	4.6306	17	45.7402	1	0.0635	34
22	EATING AT HOME	10.5270	11	0.0000	--	-----	--
23	EATING OUT	4.9121	15	3.5092	8	0.7352	26
24	SLEEP AND REST	109.0776	1	0.0000	--	-----	--
25	VACATION	4.6630	16	1.0676	22	2.6711	13
26	EDUCATION	1.0910	24	0.7736	24	3.1240	12
27	RELIGION	3.2928	19	1.1594	20	2.4717	15
28	OTHER ORGANIZATIONS	0.4484	34	2.7340	12	0.6882	27
29	TELEVISION	29.1837	3	0.0547	34	53.3922	1
30	READING	4.1008	18	0.2498	30	11.1827	5
31	SOCIAL LIFE	21.5510	5	0.6504	26	4.5147	9
32	CONVERSATION	8.4444	12	0.8413	23	3.4747	10
33	OUTDOORS	2.1961	22	0.6305	27	4.7247	8
34	ENTERTAINENT	0.9766	28	0.6950	25	3.2402	11
35	LISTENING TO SOUNDS	1.6317	23	1.1223	21	2.5170	14
36	PERFORMING	0.1582	37	1.6315	17	1.8069	18
37	HOBBIES AND CRAFTS	1.0518	26	0.4669	28	6.0899	7
38	PERSONAL LETTERS	0.5934	32	0.4186	29	6.7714	6
	TOTAL	373.0007		0.6758		4.2187	

ASSUMPTIONS ABOUT THE THE UNDER $5000 HOUSEHOLD INCOME CLASS

	WAGE RATE ($/HOUR AFTER TAX)	POPULATION (MILLIONS)
EMPLOYED MEN	2.76	2.07
EMPLOYED WOMEN	1.52	1.29
HOUSEWIVES	3.07	8.71

TOTAL NUMBER OF HOUSEHOLDS 17.61 MILLION

VALUE OF TIME VS. MARKET EXPENDITURES FOR THE $5000-7999 HOUSEHOLD INCOME CLASS

	ACTIVITY	MINUTES/DAY EMPLOYED MEN	MINUTES/DAY EMPLOYED WOMEN	MINUTES/DAY HOUSEWIVES	1973 $/HOUSEHOLD MARKET EXPENDITURES	BILLION 1973 $ EMPLOYED MEN VALUE OF TIME	BILLION 1973 $ EMPLOYED WOMEN VALUE OF TIME	BILLION 1973 $ HOUSEWIVES VALUE OF TIME	BILLION 1973 $ TOTAL VALUE OF TIME	BILLION 1973 $ TOTAL MARKET EXPENDITURES	PERSON HOURS (MILLIONS)
1	JOB	365.94	294.95	3.12	0.0	33.35	9.25	0.29	42.88	0.00	14713.2
2	TRAVEL TO JOB	32.70	23.63	0.53	383.2	2.98	0.74	0.05	3.77	4.02	1277.6
3	FOOD PREPARATION	25.64	84.75	167.27	1108.4	2.34	2.66	15.53	20.52	11.63	7368.2
4	HOUSE CLEANING	6.71	42.47	83.68	35.2	0.61	1.33	7.77	9.71	0.37	3524.8
5	GARDENING	1.63	0.87	1.65	33.5	0.15	0.03	0.15	0.33	0.35	109.8
6	PET CARE	1.19	0.70	1.21	48.6	0.11	0.02	0.11	0.24	0.51	81.3
7	CLOTHING AND LINENS	7.31	33.50	65.63	586.0	0.67	1.05	6.09	7.81	6.15	2822.1
8	HOUSE	13.30	7.65	10.54	1565.1	1.21	0.24	0.98	2.43	16.42	813.2
9	MEDICAL CARE GIVEN	0.52	0.62	0.83	69.6	0.05	0.02	0.08	0.14	0.73	50.3
10	CHILD CARE	10.24	21.27	60.70	99.1	0.93	0.67	5.53	7.23	1.04	2541.2
11	FINANCIAL MANAGEMENT	19.38	42.53	39.11	420.1	1.77	1.33	3.63	6.73	4.41	2455.1
12	TRAVEL/PRO MEDICAL	0.45	0.51	0.32	21.7	0.04	0.02	0.03	0.09	0.23	30.4
13	TRAVEL/EDUCATION	0.61	0.45	0.70	10.8	0.06	0.01	0.06	0.14	0.11	45.9
14	TRAVEL/ORG & RELIGION	2.46	2.72	3.50	57.4	0.22	0.09	0.32	0.63	0.60	220.9
15	TRAVEL/SOCAL LIFE	7.37	9.05	9.10	168.9	0.67	0.28	0.84	1.80	1.77	633.5
16	TRAVEL/LEISURE	1.23	1.81	1.40	29.2	0.11	0.06	0.13	0.30	0.31	106.9
17	SHOPPING/NON-TRADABLE	5.89	8.25	7.11	93.1	0.54	0.26	0.66	1.46	0.98	517.9
	TOTAL--TRADABLE	502.57	575.74	456.41	4729.9	45.79	18.05	42.37	106.21	49.62	37312.4
18	PERSONAL CARE @HOME	50.21	72.57	69.67	59.1	4.58	2.28	6.47	13.32	0.62	4737.4
19	PERSONAL CARE SERVICES	0.88	1.96	2.02	48.5	0.08	0.06	0.19	0.33	0.51	119.7
20	MED CARE RECEIVE @HOME	0.22	0.25	0.50	0.0	0.02	0.01	0.05	0.07	0.00	25.9
21	PRO MEDICAL CARE	0.88	0.98	2.02	387.8	0.08	0.03	0.19	0.30	4.07	103.4
22	EATING AT HOME	64.11	43.83	70.41	0.0	5.84	1.37	6.54	13.75	0.00	4653.3
23	EATING OUT	35.99	21.91	5.95	290.5	3.28	0.69	0.55	4.52	3.05	1507.5
24	SLEEP AND REST	462.47	455.50	477.83	0.0	42.14	14.28	44.35	100.78	0.00	34928.8
25	VACATION	30.47	30.53	30.65	126.7	2.78	0.96	2.85	6.58	1.33	2283.6
26	EDUCATION	2.98	4.55	0.00	25.4	0.27	0.14	0.00	0.41	0.27	154.7
27	RELIGION	6.55	10.36	11.50	94.0	0.60	0.32	1.07	1.99	0.99	709.1
28	OTHER ORGANIZATIONS	4.69	2.10	2.67	17.8	0.43	0.07	0.25	0.74	0.19	243.8
29	TELEVISION	130.87	59.60	116.67	54.2	11.93	1.87	10.83	24.62	0.57	8149.0
30	READING	25.69	24.06	36.34	32.1	2.34	0.75	3.37	6.47	0.34	2229.0
31	SOCIAL LIFE	64.22	89.48	88.94	389.1	5.85	2.81	8.26	16.91	4.08	5998.6
32	CONVERSATION	11.12	14.88	26.18	154.8	1.01	0.47	2.43	3.91	1.62	1368.9
33	OUTDOORS	14.21	2.77	2.07	51.6	1.30	0.09	0.19	1.57	0.54	488.9
34	ENTERTAINENT	22.94	10.66	10.30	33.2	2.09	0.33	0.96	3.38	0.35	1111.6
35	LISTENING TO SOUNDS	4.13	6.90	6.08	44.8	0.38	0.22	0.56	1.16	0.47	416.1
36	PERFORMING	0.50	0.34	1.61	6.3	0.05	0.01	0.15	0.21	0.07	70.0
37	HOBBIES AND CRAFTS	2.77	6.89	14.10	15.8	0.25	0.22	1.31	1.78	0.17	633.2
38	PERSONAL LETTERS	1.51	4.13	8.06	7.2	0.14	0.13	0.75	1.02	0.08	363.2
	TOTAL	1440.00	1440.00	1440.00	6568.7	131.21	45.15	133.67	310.03	68.91	107607.4

CONTINUATION OF VALUE OF TIME VS. MARKET EXPENDITURES FOR THE $5000-7999 HOUSEHOLD INCOME CLASS

		TOTAL EXPENSE BILLION $	RANK	MARKET EXPENDITURES PER HOUR	RANK	RATIO TIME VALUE/ MARKET EXPENDITURES	RANK
1	JOB	42.8829	2	0.0000	--	-----	--
2	TRAVEL TO JOB	7.7904	14	3.1468	8	0.9378	27
3	FOOD PREPARATION	32.1470	3	1.5780	18	1.7648	17
4	HOUSE CLEANING	10.0801	11	0.1049	33	26.2702	2
5	GARDENING	0.6803	33	3.2024	7	0.9353	28
6	PET CARE	0.7517	31	6.2641	5	0.4755	30
7	CLOTHING AND LINENS	13.9556	7	2.1781	13	1.2703	22
8	HOUSE	18.8483	6	20.1898	2	0.1481	33
9	MEDICAL CARE GIVEN	0.8739	29	14.5055	3	0.1971	32
10	CHILD CARE	8.2732	12	0.4089	27	6.9613	8
11	FINANCIAL MANAGEMENT	11.1364	10	1.7950	16	1.5270	19
12	TRAVEL/PRO MEDICAL	0.3136	35	7.4620	4	0.3807	31
13	TRAVEL/EDUCATION	0.2487	37	2.4711	12	1.1907	23
14	TRAVEL/ORG & RELIGION	1.2360	26	2.7249	11	1.0535	24
15	TRAVEL/SOCAL LIFE	3.5724	20	2.7968	10	1.0164	25
16	TRAVEL/LEISURE	0.6054	34	2.8680	9	0.9744	26
17	SHOPPING/NON-TRADABLE	2.4323	22	1.8859	15	1.4902	20
	TOTAL--TRADABLE	155.8280		1.3298		2.1407	
18	PERSONAL CARE @HOME	13.9375	8	0.1308	32	21.4839	3
19	PERSONAL CARE SERVICES	0.8378	30	4.2489	6	0.6473	29
20	MED CARE RECEIVE @HOME	0.0746	38	0.0000	--	-----	--
21	PRO MEDICAL CARE	4.3663	18	39.3300	1	0.0734	34
22	EATING AT HOME	13.7516	9	0.0000	--	-----	--
23	EATING OUT	7.5664	15	2.0215	14	1.4828	21
24	SLEEP AND REST	100.7766	1	0.0000	--	-----	--
25	VACATION	7.9080	13	0.5822	26	4.9481	9
26	EDUCATION	0.6803	32	1.7203	17	1.5566	18
27	RELIGION	2.9759	21	1.3911	19	2.0171	16
28	OTHER ORGANIZATIONS	0.9285	28	0.7674	24	3.9621	11
29	TELEVISION	25.1918	4	0.0697	34	43.3383	1
30	READING	6.8058	16	0.1512	31	19.1868	4
31	SOCIAL LIFE	20.9946	5	0.6804	25	4.1439	10
32	CONVERSATION	5.5340	17	1.1862	20	2.4079	15
33	OUTDOORS	2.1152	23	1.1069	22	2.9087	13
34	ENTERTAINENT	3.7293	19	0.3133	28	9.7074	7
35	LISTENING TO SOUNDS	1.6269	25	1.1295	21	2.4614	14
36	PERFORMING	0.2720	36	0.9389	23	3.1397	12
37	HOBBIES AND CRAFTS	1.9434	24	0.2619	29	10.7215	6
38	PERSONAL LETTERS	1.0910	27	0.2082	30	13.4320	5
	TOTAL	378.9343		0.6403		4.4993	

ASSUMPTIONS ABOUT THE THE $5000-7999 HOUSEHOLD INCOME CLASS

	WAGE RATE ($/HOUR AFTER TAX)	POPULATION (MILLIONS)
EMPLOYED MEN	3.43	4.37
EMPLOYED WOMEN	1.89	2.73
HOUSEWIVES	2.94	5.19

TOTAL NUMBER OF HOUSEHOLDS 10.49 MILLION

VALUE OF TIME VS. MARKET EXPENDITURES FOR THE $8000-9999 HOUSEHOLD INCOME CLASS

	ACTIVITY	MINUTES/DAY			1973	BILLION 1973 $					
		EMPLOYED MEN	EMPLOYED WOMEN	HOUSE-WIVES	$/HOUSE-HOLD MARKET EXPEND-ITURES	EMPLOYED MEN VALUE OF TIME	EMPLOYED WOMEN VALUE OF TIME	HOUSE-WIVES VALUE OF TIME	TOTAL VALUE OF TIME	TOTAL MARKET EXPEND-ITURES	PERSON HOURS (MIL-LIONS)
1	JOB	391.63	268.20	2.64	0.0	38.65	9.09	0.16	47.89	0.00	15005.2
2	TRAVEL TO JOB	39.36	27.37	0.35	505.5	3.88	0.93	0.02	4.83	3.52	1516.8
3	FOOD PREPARATION	23.07	84.88	157.98	1284.5	2.28	2.88	9.39	14.54	8.94	5339.7
4	HOUSE CLEANING	8.18	37.36	81.45	47.0	0.81	1.27	4.84	6.91	0.33	2546.8
5	GARDENING	1.27	2.04	2.72	37.9	0.13	0.07	0.16	0.36	0.26	124.9
6	PET CARE	0.95	1.51	1.96	61.9	0.09	0.05	0.12	0.26	0.43	91.6
7	CLOTHING AND LINENS	9.76	45.85	66.74	739.1	0.96	1.55	3.97	6.48	5.14	2422.8
8	HOUSE	10.77	8.27	12.77	1834.4	1.06	0.28	0.76	2.10	12.77	693.2
9	MEDICAL CARE GIVEN	0.58	0.71	0.87	80.6	0.06	0.02	0.05	0.13	0.56	45.6
10	CHILD CARE	6.40	21.76	82.77	134.1	0.63	0.74	4.92	6.29	0.93	2266.3
11	FINANCIAL MANAGEMENT	14.28	38.33	43.80	702.7	1.41	1.30	2.60	5.31	4.89	1938.2
12	TRAVEL/PRO MEDICAL	0.37	0.61	0.56	28.5	0.04	0.02	0.03	0.09	0.20	31.9
13	TRAVEL/EDUCATION	0.80	0.31	0.67	14.3	0.08	0.01	0.04	0.13	0.10	40.5
14	TRAVEL/ORG & RELIGION	3.21	1.85	3.33	75.7	0.32	0.06	0.26	0.58	0.53	186.4
15	TRAVEL/SOCAL LIFE	9.62	6.17	8.67	222.8	0.95	0.21	0.52	1.67	1.55	541.7
16	TRAVEL/LEISURE	1.60	1.23	1.33	38.6	0.16	0.04	0.08	0.28	0.27	91.4
17	SHOPPING/NON-TRADABLE	6.24	9.72	8.50	122.8	0.62	0.33	0.51	1.45	0.85	507.0
	TOTAL--TRADABLE	528.08	556.16	477.11	5930.6	52.11	18.85	28.36	99.31	41.28	33390.1
18	PERSONAL CARE @HOME	63.33	71.25	60.42	71.0	6.25	2.41	3.59	12.25	0.49	4147.2
19	PERSONAL CARE SERVICES	1.11	1.93	1.75	78.9	0.11	0.07	0.10	0.28	0.55	98.5
20	MED CARE RECEIVE @HOME	0.28	0.24	0.44	0.0	0.03	0.01	0.03	0.06	0.00	20.6
21	PRO MEDICAL CARE	1.11	0.96	1.75	458.0	0.11	0.03	0.10	0.25	3.19	82.4
22	EATING AT HOME	54.79	49.74	75.17	0.0	5.41	1.69	4.47	11.56	0.00	3868.5
23	EATING OUT	30.76	24.87	6.35	374.7	3.04	0.84	0.38	4.26	2.61	1370.6
24	SLEEP AND REST	459.44	470.32	476.65	0.0	45.34	15.94	28.33	89.60	0.00	30112.0
25	VACATION	33.83	33.76	33.95	176.5	3.34	1.14	2.02	6.50	1.23	2178.8
26	EDUCATION	4.90	0.96	0.60	42.9	0.48	0.03	0.04	0.55	0.30	159.6
27	RELIGION	8.75	4.29	14.63	117.1	0.86	0.15	0.87	1.88	0.82	611.9
28	OTHER ORGANIZATIONS	5.38	6.44	11.99	27.2	0.53	0.22	0.71	1.46	0.19	502.3
29	TELEVISION	95.88	67.43	101.26	64.3	9.46	2.29	6.02	17.76	0.45	5808.6
30	READING	30.62	24.76	31.84	41.0	3.02	0.84	1.89	5.75	0.29	1898.6
31	SOCIAL LIFE	81.40	66.20	83.06	479.3	8.03	2.24	4.94	15.21	3.34	5020.2
32	CONVERSATION	8.95	13.96	23.10	172.2	0.88	0.47	1.37	2.73	1.20	955.8
33	OUTDOORS	12.42	10.11	9.24	89.3	1.23	0.34	0.55	2.12	0.62	694.4
34	ENTERTAINENT	7.61	4.39	4.68	36.6	0.75	0.15	0.28	1.18	0.25	374.6
35	LISTENING TO SOUNDS	5.13	5.06	2.50	54.7	0.51	0.17	0.15	0.83	0.38	274.0
36	PERFORMING	0.66	0.82	1.59	11.9	0.06	0.03	0.09	0.19	0.08	64.6
37	HOBBIES AND CRAFTS	3.60	16.47	13.95	26.4	0.36	0.56	0.83	1.74	0.18	663.1
38	PERSONAL LETTERS	1.97	9.88	7.97	8.0	0.19	0.33	0.47	1.00	0.06	384.3
	TOTAL	1440.00	1440.00	1440.00	8260.5	142.10	48.80	85.58	276.47	57.49	92680.4

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CONTINUATION OF VALUE OF TIME VS. MARKET EXPENDITURES FOR THE $8000-9999 HOUSEHOLD INCOME CLASS

		TOTAL EXPENSE BILLION $	RANK	MARKET EXPENDITURES PER HOUR	RANK	RATIO TIME VALUE/ MARKET EXPENDITURES	RANK
1	JOB	47.8905	2	0.0000	--	-----	--
2	TRAVEL TO JOB	8.3508	11	2.3196	12	1.3734	21
3	FOOD PREPARATION	23.4819	3	1.6743	18	1.6265	20
4	HOUSE CLEANING	7.2409	13	0.1285	32	21.1262	3
5	GARDENING	0.6197	33	2.1102	14	1.3509	22
6	PET CARE	0.6923	32	4.7047	6	0.6062	29
7	CLOTHING AND LINENS	11.6270	8	2.1233	13	1.2601	24
8	HOUSE	14.8695	6	18.4171	2	0.1646	33
9	MEDICAL CARE GIVEN	0.6945	31	12.3116	3	0.2373	32
10	CHILD CARE	7.2212	14	0.4120	27	6.7346	8
11	FINANCIAL MANAGEMENT	10.2013	10	2.5233	10	1.0859	26
12	TRAVEL/PRO MEDICAL	0.2896	35	6.2287	4	0.4574	31
13	TRAVEL/EDUCATION	0.2286	37	2.4517	11	1.2998	23
14	TRAVEL/ORG & RELIGION	1.1042	27	2.8258	9	1.0959	25
15	TRAVEL/SOCAL LIFE	3.2242	19	2.8625	8	1.0794	27
16	TRAVEL/LEISURE	0.5477	34	2.9366	7	1.0408	28
17	SHOPPING/NON-TRADABLE	2.3050	22	1.6859	17	1.6966	18
	TOTAL--TRADABLE	140.5887		1.2362		2.4060	
18	PERSONAL CARE @HOME	12.7479	7	0.1191	33	24.8103	2
19	PERSONAL CARE SERVICES	0.8279	30	5.5728	5	0.5082	30
20	MED CARE RECEIVE @HOME	0.0616	38	0.0000	--	-----	--
21	PRO MEDICAL CARE	3.4339	18	38.6705	1	0.0773	34
22	EATING AT HOME	11.5595	9	0.0000	--	-----	--
23	EATING OUT	6.8633	15	1.9026	15	1.6319	19
24	SLEEP AND REST	89.6023	1	0.0000	--	-----	--
25	VACATION	7.7291	12	0.5640	26	5.2903	9
26	EDUCATION	0.8502	29	1.8708	16	1.8477	17
27	RELIGION	2.6939	21	1.3322	20	2.3047	13
28	OTHER ORGANIZATIONS	1.6510	24	0.3768	28	7.7235	7
29	TELEVISION	18.2118	5	0.0771	34	39.6723	1
30	READING	6.0383	16	0.1501	30	20.1837	4
31	SOCIAL LIFE	18.5488	4	0.6645	25	4.5601	11
32	CONVERSATION	3.9275	17	1.2538	22	2.2775	14
33	OUTDOORS	2.7392	20	0.8948	23	3.4083	12
34	ENTERTAINENT	1.4323	25	0.6803	24	4.6197	10
35	LISTENING TO SOUNDS	1.2075	26	1.3904	19	2.1693	16
36	PERFORMING	0.2701	36	1.2818	21	2.2611	15
37	HOBBIES AND CRAFTS	1.9262	23	0.2770	29	9.4871	6
38	PERSONAL LETTERS	1.0583	28	0.1453	31	17.9538	5
	TOTAL	333.9683		0.6203		4.8088	

ASSUMPTIONS ABOUT THE THE $8000-9999 HOUSEHOLD INCOME CLASS

	WAGE RATE ($/HOUR AFTER TAX)	POPULATION (MILLIONS)
EMPLOYED MEN	3.69	4.40
EMPLOYED WOMEN	2.03	2.74
HOUSEWIVES	2.84	3.44

TOTAL NUMBER OF HOUSEHOLDS 6.96 MILLION

VALUE OF TIME VS. MARKET EXPENDITURES FOR THE $10,000-11,999 HOUSEHOLD INCOME CLASS

	ACTIVITY	MINUTES/DAY			1973	BILLION 1973 $					
		EMPLOYED MEN	EMPLOYED WOMEN	HOUSE-WIVES	$/HOUSE-HOLD MARKET EXPEND-ITURES	EMPLOYED MEN VALUE OF TIME	EMPLOYED WOMEN VALUE OF TIME	HOUSE-WIVES VALUE OF TIME	TOTAL VALUE OF TIME	TOTAL MARKET EXPEND-ITURES	PERSON HOURS (MIL-LIONS)
1	JOB	400.67	309.90	0.00	0.0	49.74	13.23	0.00	62.97	0.00	19721.5
2	TRAVEL TO JOB	40.25	27.15	0.00	617.0	5.00	1.16	0.00	6.16	4.09	1898.8
3	FOOD PREPARATION	23.21	99.87	147.93	1393.9	2.88	4.26	8.24	15.38	9.24	5791.9
4	HOUSE CLEANING	6.84	45.06	74.85	50.1	0.85	1.92	4.17	6.94	0.33	2654.7
5	GARDENING	2.40	1.80	5.55	46.5	0.30	0.08	0.31	0.68	0.31	227.6
6	PET CARE	1.73	1.32	3.84	70.7	0.21	0.06	0.21	0.48	0.47	161.3
7	CLOTHING AND LINENS	7.15	45.96	69.81	862.4	0.89	1.96	3.89	6.74	5.72	2582.8
8	HOUSE	15.50	6.74	10.29	1983.5	1.92	0.29	0.57	2.78	13.15	859.2
9	MEDICAL CARE GIVEN	0.62	0.61	0.94	75.8	0.08	0.03	0.05	0.16	0.50	52.1
10	CHILD CARE	9.67	28.96	80.22	157.6	1.20	1.24	4.47	6.90	1.04	2521.8
11	FINANCIAL MANAGEMENT	23.70	26.35	36.03	919.1	2.94	1.12	2.01	6.07	6.09	2051.7
12	TRAVEL/PRO MEDICAL	0.52	0.53	0.57	34.9	0.07	0.02	0.03	0.12	0.23	39.7
13	TRAVEL/EDUCATION	0.82	0.35	0.72	17.4	0.10	0.01	0.04	0.16	0.12	48.7
14	TRAVEL/ORG & RELIGION	3.29	2.07	3.58	92.4	0.41	0.09	0.20	0.70	0.61	223.5
15	TRAVEL/SOCAL LIFE	9.86	6.90	9.32	271.9	1.22	0.29	0.52	2.04	1.80	656.1
16	TRAVEL/LEISURE	1.64	1.38	1.43	47.1	0.20	0.06	0.08	0.34	0.31	111.[illegible]
17	SHOPPING/NON-TRADABLE	7.91	7.28	8.06	149.9	0.98	0.31	0.45	1.74	0.99	574.3
	TOTAL--TRADABLE	555.79	612.22	453.13	6790.0	68.99	26.14	25.23	120.36	45.02	40177.5
18	PERSONAL CARE @HOME	55.25	70.23	72.73	85.3	6.86	3.00	4.05	13.91	0.57	4740.7
19	PERSONAL CARE SERVICES	0.97	1.90	2.11	93.2	0.12	0.08	0.12	0.32	0.62	113.6
20	MED CARE RECEIVE @HOME	0.24	0.24	0.53	0.0	0.03	0.01	0.03	0.07	0.00	23.5
21	PRO MEDICAL CARE	0.97	0.95	2.11	488.8	0.12	0.04	0.12	0.28	3.24	93.9
22	EATING AT HOME	53.02	44.25	68.45	0.0	6.58	1.89	3.81	12.28	0.00	4042.9
23	EATING OUT	29.77	22.12	5.78	444.6	3.70	0.94	0.32	4.96	2.95	1562.0
24	SLEEP AND REST	450.28	479.97	488.79	0.0	55.90	20.49	27.21	103.60	0.00	34646.1
25	VACATION	27.74	27.74	27.66	214.2	3.44	1.18	1.54	6.17	1.42	2047.3
26	EDUCATION	13.14	2.50	1.40	65.4	1.63	0.11	0.08	1.82	0.43	515.9
27	RELIGION	8.11	9.25	14.36	138.9	1.01	0.39	0.80	2.20	0.92	747.4
28	OTHER ORGANIZATIONS	9.08	0.35	6.73	37.4	1.13	0.02	0.37	1.52	0.25	443.2
29	TELEVISION	101.72	45.45	100.11	66.1	12.63	1.94	5.57	20.14	0.44	6315.6
30	READING	34.70	20.02	39.04	45.3	4.31	0.85	2.17	7.34	0.30	2345.6
31	SOCIAL LIFE	54.00	54.88	83.58	496.1	6.70	2.34	4.65	13.70	3.29	4597.5
32	CONVERSATION	14.51	23.87	32.77	184.0	1.80	1.02	1.82	4.64	1.22	1630.2
33	OUTDOORS	10.77	6.62	2.51	118.5	1.34	0.28	0.14	1.76	0.79	544.8
34	ENTERTAINENT	4.19	4.63	6.18	49.6	0.52	0.20	0.34	1.06	0.33	358.4
35	LISTENING TO SOUNDS	5.35	2.39	2.48	59.1	0.66	0.10	0.14	0.90	0.39	276.6
36	PERFORMING	1.09	0.32	2.00	12.1	0.14	0.01	0.11	0.26	0.08	82.8
37	HOBBIES AND CRAFTS	6.02	6.32	17.51	31.8	0.75	0.27	0.97	1.99	0.21	680.2
38	PERSONAL LETTERS	3.28	3.79	10.01	8.8	0.41	0.16	0.56	1.13	0.06	387.2
	TOTAL	1440.00	1440.00	1440.00	9428.8	178.75	61.48	80.16	320.40	62.51	106372.3

CONTINUATION OF VALUE OF TIME VS. MARKET EXPENDITURES FOR THE $10,000-11,999 HOUSEHOLD INCOME CLASS

		TOTAL EXPENSE BILLION $	RANK	MARKET EXPENDITURES PER HOUR	RANK	RATIO TIME VALUE/ MARKET EXPENDITURES	RANK
1	JOB	62.9676	2	0.0000	--	-----	--
2	TRAVEL TO JOB	10.2470	11	2.1543	13	1.5049	22
3	FOOD PREPARATION	24.6222	3	1.5956	16	1.6642	21
4	HOUSE CLEANING	7.2726	16	0.1250	32	20.9141	4
5	GARDENING	0.9920	30	1.3546	19	2.2172	18
6	PET CARE	0.9530	31	2.9041	7	1.0344	28
7	CLOTHING AND LINENS	12.4535	8	2.2137	12	1.1781	24
8	HOUSE	15.9341	6	15.3060	2	0.2117	33
9	MEDICAL CARE GIVEN	0.6588	33	9.6483	3	0.3100	32
10	CHILD CARE	7.9477	12	0.4144	28	6.6056	7
11	FINANCIAL MANAGEMENT	12.1660	10	2.9700	6	0.9966	29
12	TRAVEL/PRO MEDICAL	0.3504	35	5.8216	4	0.5162	30
13	TRAVEL/EDUCATION	0.2721	37	2.3718	11	1.3553	23
14	TRAVEL/ORG C RELIGION	1.3082	27	2.7405	10	1.1361	25
15	TRAVEL/SOCAL LIFE	3.8396	18	2.7476	9	1.1299	26
16	TRAVEL/LEISURE	0.6547	34	2.7925	8	1.0982	27
17	SHOPPING/NON-TRADABLE	2.7355	21	1.7305	15	1.7525	19
	TOTAL--TRADABLE	165.3750		1.1205		2.6735	
18	PERSONAL CARE @HOME	14.4714	7	0.1193	33	24.5946	2
19	PERSONAL CARE SERVICES	0.9369	32	5.4428	5	0.5156	31
20	MED CARE RECEIVE @HOME	0.0696	38	0.0000	--	-----	--
21	PRO MEDICAL CARE	3.5187	19	34.5064	1	0.0859	34
22	EATING AT HOME	12.2820	9	0.0000	--	-----	--
23	EATING OUT	7.9092	13	1.8870	14	1.6835	20
24	SLEEP AND REST	103.5986	1	0.0000	--	-----	--
25	VACATION	7.5871	15	0.6937	26	4.3421	9
26	EDUCATION	2.2493	23	0.8402	23	4.1893	10
27	RELIGION	3.1216	20	1.2317	20	2.3909	15
28	OTHER ORGANIZATIONS	1.7653	25	0.5590	27	6.1260	8
29	TELEVISION	20.5784	4	0.0694	34	45.9413	1
30	READING	7.6356	14	0.1280	31	24.4362	3
31	SOCIAL LIFE	16.9884	5	0.7154	25	4.1653	11
32	CONVERSATION	5.8642	17	0.7482	24	3.8077	12
33	OUTDOORS	2.5450	22	1.4423	17	2.2389	17
34	ENTERTAINENT	1.3908	26	0.9169	22	3.2322	14
35	LISTENING TO SOUNDS	1.2957	28	1.4158	18	2.3087	16
36	PERFORMING	0.3408	36	0.9655	21	3.2616	13
37	HOBBIES AND CRAFTS	2.2028	24	0.3098	29	9.4541	6
38	PERSONAL LETTERS	1.1850	29	0.1507	30	19.3017	5
	TOTAL	382.9089		0.5877		5.1252	

ASSUMPTIONS ABOUT THE THE $10,000-11,999 HOUSEHOLD INCOME CLASS

	WAGE RATE ($/HOUR AFTER TAX)	POPULATION (MILLIONS)
EMPLOYED MEN	3.74	5.46
EMPLOYED WOMEN	2.06	3.41
HOUSEWIVES	2.79	3.28

TOTAL NUMBER OF HOUSEHOLDS 6.63 MILLION

VALUE OF TIME VS. MARKET EXPENDITURES FOR THE $12,000-19,999 HOUSEHOLD INCOME CLASS

	ACTIVITY	MINUTES/DAY			1973	BILLION 1973 $					
		EMPLOYED MEN	EMPLOYED WOMEN	HOUSE-WIVES	$/HOUSE-HOLD MARKET EXPEND-ITURES	EMPLOYED MEN VALUE OF TIME	EMPLOYED WOMEN VALUE OF TIME	HOUSE-WIVES VALUE OF TIME	TOTAL VALUE OF TIME	TOTAL MARKET EXPEND-ITURES	PERSON HOURS (MIL-LIONS)
1	JOB	391.26	325.40	10.42	0.0	203.64	58.02	1.66	263.32	0.00	77763.0
2	TRAVEL TO JOB	38.09	31.29	0.36	759.4	19.82	5.58	0.06	25.46	14.73	7500.5
3	FOOD PREPARATION	26.68	84.73	152.17	1678.4	13.89	15.11	24.24	53.23	32.56	19207.1
4	HOUSE CLEANING	8.21	41.84	74.00	65.0	4.27	7.45	11.79	23.51	1.26	8772.3
5	GARDENING	1.32	2.06	3.12	67.5	0.69	0.37	0.50	1.55	1.31	520.8
6	PET CARE	1.02	1.52	2.23	87.4	0.53	0.27	0.36	1.16	1.70	385.4
7	CLOTHING AND LINENS	7.56	20.14	75.77	1093.1	3.93	3.59	12.07	19.59	21.21	7032.7
8	HOUSE	18.81	6.20	10.48	2415.5	9.79	1.11	1.67	12.57	46.86	3555.5
9	MEDICAL CARE GIVEN	0.65	0.65	0.93	100.4	0.34	0.12	0.15	0.60	1.95	191.2
10	CHILD CARE	8.69	19.29	69.52	197.4	4.52	3.44	11.07	19.03	3.83	6746.1
11	FINANCIAL MANAGEMENT	20.17	23.07	36.90	1304.8	10.50	4.11	5.88	20.49	25.31	6640.8
12	TRAVEL/PRO MEDICAL	0.60	0.50	0.57	42.9	0.31	0.09	0.09	0.49	0.83	151.1
13	TRAVEL/EDUCATION	0.79	0.46	0.83	21.5	0.41	0.08	0.13	0.62	0.42	187.5
14	TRAVEL/ORG & RELIGION	3.14	2.77	4.13	113.7	1.64	0.49	0.66	2.79	2.21	872.9
15	TRAVEL/SOCAL LIFE	9.43	9.23	10.73	334.7	4.91	1.65	1.71	8.26	6.49	2597.3
16	TRAVEL/LEISURE	1.57	1.85	1.65	57.9	0.82	0.33	0.26	1.41	1.12	449.8
17	SHOPPING/NON-TRADABLE	7.69	8.87	9.06	184.5	4.00	1.58	1.44	7.03	3.58	2245.3
	TOTAL--TRADABLE	545.66	579.84	462.87	8524.0	284.00	103.38	73.72	461.10	165.37	144819.0
18	PERSONAL CARE @HOME	54.51	64.21	66.10	102.0	28.37	11.45	10.53	50.35	1.98	16135.3
19	PERSONAL CARE SERVICES	0.96	1.74	1.92	118.6	0.50	0.31	0.31	1.11	2.30	376.5
20	MED CARE RECEIVE @HOME	0.24	0.22	0.48	0.0	0.12	0.04	0.08	0.24	0.00	76.6
21	PRO MEDICAL CARE	0.96	0.87	1.92	569.2	0.50	0.15	0.31	0.96	11.04	306.2
22	EATING AT HOME	60.81	48.93	70.09	0.0	31.65	8.72	11.16	51.53	0.00	15946.4
23	EATING OUT	34.14	24.46	5.92	568.8	17.77	4.36	0.94	23.07	11.03	6758.9
24	SLEEP AND REST	456.58	464.67	473.56	0.0	237.64	82.85	75.42	395.91	0.00	124546.4
25	VACATION	23.17	23.09	23.07	319.5	12.06	4.12	3.67	19.85	6.20	6224.7
26	EDUCATION	5.55	4.46	10.38	119.8	2.89	0.80	1.65	5.34	2.32	1687.1
27	RELIGION	4.55	2.53	15.84	195.5	2.37	0.45	2.52	5.34	3.79	1719.1
28	OTHER ORGANIZATIONS	6.83	2.18	19.18	58.2	3.56	0.39	3.05	7.00	1.13	2182.5
29	TELEVISION	85.00	57.76	74.03	78.9	44.24	10.30	11.79	66.33	1.53	20032.2
30	READING	43.10	30.94	33.46	60.2	22.43	5.52	5.33	33.28	1.17	10053.8
31	SOCIAL LIFE	49.58	73.06	97.11	621.8	25.80	13.03	15.47	54.30	12.06	18020.9
32	CONVERSATION	13.33	13.57	31.12	210.6	6.94	2.42	4.96	14.31	4.08	4645.6
33	OUTDOORS	16.49	9.57	1.09	199.5	8.58	1.71	0.17	10.46	3.87	2980.0
34	ENTERTAINENT	21.61	14.23	5.21	62.6	11.25	2.54	0.83	14.61	1.21	4261.9
35	LISTENING TO SOUNDS	4.07	6.26	1.78	72.5	2.12	1.12	0.28	3.52	1.41	1138.9
36	PERFORMING	1.36	0.53	3.04	23.2	0.71	0.09	0.48	1.28	0.45	396.2
37	HOBBIES AND CRAFTS	7.45	10.56	26.62	44.0	3.88	1.88	4.24	10.00	0.85	3376.0
38	PERSONAL LETTERS	4.07	6.33	15.21	12.6	2.12	1.13	2.42	5.67	0.24	1928.5
	TOTAL	1440.00	1440.00	1440.00	11961.3	749.48	256.74	229.34	1235.56	232.05	387611.9

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CONTINUATION OF VALUE OF TIME VS. MARKET EXPENDITURES FOR THE $12,000-19,999 HOUSEHOLD INCOME CLASS

		TOTAL EXPENSE BILLION $	RANK	MARKET EXPENDITURES PER HOUR	RANK	RATIO TIME VALUE/ MARKET EXPENDITURES	RANK
1	JOB	263.3188	2	0.0000	--	-----	--
2	TRAVEL TO JOB	40.1922	11	1.9641	15	1.7283	19
3	FOOD PREPARATION	85.7891	3	1.6952	16	1.6347	20
4	HOUSE CLEANING	24.7764	15	0.1438	30	18.6356	5
5	GARDENING	2.8632	31	2.5163	10	1.1849	26
6	PET CARE	2.8515	32	4.3987	6	0.6820	29
7	CLOTHING AND LINENS	40.7956	10	3.0153	8	0.9238	27
8	HOUSE	59.4268	6	13.1800	2	0.2681	33
9	MEDICAL CARE GIVEN	2.5506	33	10.1865	3	0.3093	32
10	CHILD CARE	22.8601	16	0.5676	26	4.9703	9
11	FINANCIAL MANAGEMENT	45.8027	9	3.8117	7	0.8095	28
12	TRAVEL/PRO MEDICAL	1.3223	36	5.5067	5	0.5888	30
13	TRAVEL/EDUCATION	1.0388	37	2.2197	13	1.4958	21
14	TRAVEL/ORG & RELIGION	4.9919	28	2.5268	9	1.2632	24
15	TRAVEL/SOCIAL LIFE	14.7525	19	2.4996	11	1.2723	23
16	TRAVEL/LEISURE	2.5331	34	2.4979	12	1.2547	25
17	SHOPPING/NON-TRADABLE	10.6062	23	1.5940	18	1.9634	18
	TOTAL--TRADABLE	626.4700		1.1419		2.7884	
18	PERSONAL CARE @HOME	52.3273	7	0.1226	32	25.4435	3
19	PERSONAL CARE SERVICES	3.4129	30	6.1097	4	0.4835	31
20	MED CARE RECEIVE @HOME	0.2394	38	0.0000	--	-----	--
21	PRO MEDICAL CARE	12.0002	21	36.0600	1	0.0867	34
22	EATING AT HOME	51.5343	8	0.0000	--	-----	--
23	EATING OUT	34.1067	13	1.6325	17	2.0910	17
24	SLEEP AND REST	395.9065	1	0.0000	--	-----	--
25	VACATION	26.0497	14	0.9958	23	3.2024	12
26	EDUCATION	7.6590	26	1.3772	19	2.2963	16
27	RELIGION	9.1327	24	2.2062	14	1.4079	22
28	OTHER ORGANIZATIONS	8.1291	25	0.5174	27	6.1986	8
29	TELEVISION	67.8599	4	0.0764	34	43.3185	1
30	READING	34.4454	12	0.1161	33	28.5092	2
31	SOCIAL LIFE	66.3586	5	0.6694	25	4.5008	10
32	CONVERSATION	18.3994	17	0.8793	24	3.5044	11
33	OUTDOORS	14.3344	20	1.2988	20	2.7037	14
34	ENTERTAINMENT	15.8276	18	0.2848	28	12.0386	6
35	LISTENING TO SOUNDS	4.9225	29	1.2346	21	2.5008	15
36	PERFORMING	1.7336	35	1.1348	22	2.8561	13
37	HOBBIES AND CRAFTS	10.8557	22	0.2530	29	11.7083	7
38	PERSONAL LETTERS	5.9119	27	0.1264	31	23.2578	4
	TOTAL	1467.6143		0.5987		5.3245	

ASSUMPTIONS ABOUT THE THE $12,000-19,999 HOUSEHOLD INCOME CLASS

	WAGE RATE ($/HOUR AFTER TAX)	POPULATION (MILLIONS)
EMPLOYED MEN	4.01	21.34
EMPLOYED WOMEN	2.20	13.32
HOUSEWIVES	2.73	9.59

TOTAL NUMBER OF HOUSEHOLDS 19.40 MILLION

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VALUE OF TIME VS. MARKET EXPENDITURES FOR THE OVER $20,000 HOUSEHOLD INCOME CLASS

	ACTIVITY	MINUTES/DAY			1973	BILLION 1973 $					
		EMPLOYED MEN	EMPLOYED WOMEN	HOUSE-WIVES	$/HOUSE-HOLD MARKET EXPEND-ITURES	EMPLOYED MEN VALUE OF TIME	EMPLOYED WOMEN VALUE OF TIME	HOUSE-WIVES VALUE OF TIME	TOTAL VALUE OF TIME	TOTAL MARKET EXPEND-ITURES	PERSON HOURS (MIL-LIONS)
1	JOB	374.25	292.64	4.25	0.0	185.69	49.87	0.34	235.90	0.00	48696.6
2	TRAVEL TO JOB	52.92	32.23	1.42	1036.3	26.26	5.49	0.11	31.86	10.49	6412.6
3	FOOD PREPARATION	23.55	79.79	146.63	2097.6	11.69	13.60	11.80	37.08	21.23	10866.5
4	HOUSE CLEANING	7.42	49.76	74.47	122.5	3.68	8.48	5.99	18.15	1.24	5625.8
5	GARDENING	1.45	4.96	4.67	122.6	0.72	0.85	0.38	1.94	1.24	538.5
6	PET CARE	1.07	3.44	3.34	108.0	0.53	0.59	0.27	1.39	1.09	382.4
7	CLOTHING AND LINENS	6.62	30.51	44.35	1726.7	3.29	5.20	3.57	12.05	17.47	3590.1
8	HOUSE	19.38	7.68	18.69	3482.6	9.62	1.31	1.50	12.43	35.24	2678.2
9	MEDICAL CARE GIVEN	0.55	0.64	1.23	136.0	0.27	0.11	0.10	0.48	1.38	120.2
10	CHILD CARE	6.58	18.74	56.45	253.0	3.27	3.19	4.54	11.00	2.56	3314.7
11	FINANCIAL MANAGEMENT	22.60	35.48	62.37	2129.6	11.21	6.05	5.02	22.28	21.55	5803.1
12	TRAVEL/FRO MEDICAL	0.46	0.57	0.90	58.5	0.23	0.10	0.07	0.40	0.59	98.8
13	TRAVEL/EDUCATION	0.69	0.32	0.92	29.3	0.34	0.05	0.07	0.4[illegible]	0.30	106.2
14	TRAVEL/ORG & RELIGION	2.78	1.93	4.62	155.2	1.38	0.33	0.37	2.08	1.57	487.9
15	TRAVEL/SOCAL LIFE	8.33	6.44	12.00	456.7	4.13	1.10	0.97	6.19	4.62	1442.4
16	TRAVEL/LEISURE	1.39	1.29	1.85	79.0	0.69	0.22	0.15	1.06	0.80	247.4
17	SHOPPING/NON-TRADABLE	6.45	8.09	13.17	251.8	3.20	1.38	1.06	5.64	2.55	1404.0
	TOTAL--TRADABLE	536.49	574.48	451.33	12245.4	266.19	97.90	36.31	400.40	123.92	91814.9
18	PERSONAL CARE @HOME	51.31	73.70	76.78	131.1	25.46	12.56	6.18	44.20	1.33	10827.4
19	PERSONAL CARE SERVICES	0.90	1.99	2.23	186.1	0.45	0.34	0.18	0.97	1.88	254.8
20	MED CARE RECEIVE @HOME	0.23	0.25	0.56	0.0	0.11	0.04	0.04	0.20	0.00	50.1
21	PRO MEDICAL CARE	0.90	1.00	2.23	772.2	0.45	0.17	0.18	0.80	7.81	200.6
22	EATING AT HOME	51.86	53.80	69.49	0.0	25.73	9.17	5.59	40.49	0.00	9569.3
23	EATING OUT	29.12	26.90	5.87	883.7	14.45	4.58	0.47	19.50	8.94	4182.4
24	SLEEP AND REST	481.81	468.03	471.25	0.0	239.05	79.76	37.92	356.73	0.00	81857.9
25	VACATION	21.66	21.65	21.67	717.6	10.75	3.69	1.74	16.18	7.26	3727.6
26	EDUCATION	13.05	4.88	13.11	388.2	6.47	0.83	1.05	8.36	3.93	1802.8
27	RELIGION	6.23	13.35	9.95	362.4	3.09	2.28	0.80	6.17	3.67	1573.7
28	OTHER ORGANIZATIONS	0.22	0.00	9.00	208.6	0.11	0.00	0.72	0.83	2.11	293.2
29	TELEVISION	74.07	48.32	65.73	90.4	36.75	8.23	5.29	50.28	0.91	11093.4
30	READING	57.26	38.74	57.68	96.1	28.41	6.60	4.64	39.65	0.97	8859.9
31	SOCIAL LIFE	67.61	39.58	112.29	1170.5	33.54	6.74	9.03	49.32	11.85	11472.3
32	CONVERSATION	13.92	26.19	28.32	263.3	6.91	4.46	2.28	13.65	2.66	3503.0
33	OUTDOORS	11.06	5.07	1.14	399.3	5.49	0.86	0.09	6.45	4.04	1275.7
34	ENTERTAINENT	2.57	13.49	14.33	111.4	1.28	2.30	1.15	4.73	1.13	1395.4
35	LISTENING TO SOUNDS	10.71	7.50	1.61	105.7	5.32	1.28	0.13	6.72	1.07	1391.4
36	PERFORMING	0.95	0.64	1.73	58.0	0.47	0.11	0.14	0.72	0.59	170.1
37	HOBBIES AND CRAFTS	5.22	12.77	15.10	76.9	2.59	2.18	1.22	5.98	0.78	1610.8
38	PERSONAL LETTERS	2.85	7.66	8.63	16.8	1.41	1.31	0.69	3.41	0.17	928.5
	TOTAL	1440.00	1440.00	1440.00	18283.4	714.47	245.40	115.86	1075.73	185.03	247854.5

CONTINUATION OF VALUE OF TIME VS. MARKET EXPENDITURES FOR THE OVER $20,000 HOUSEHOLD INCOME CLASS

		TOTAL EXPENSE BILLION $	RANK	MARKET EXPENDITURES PER HOUR	RANK	RATIO TIME VALUE/ MARKET EXPENDITURES	RANK
1	JOB	235.8998	2	0.0000	--	-----	--
2	TRAVEL TO JOB	42.3510	9	1.6355	23	3.0382	12
3	FOOD PREPARATION	58.3070	4	1.9535	20	1.7468	17
4	HOUSE CLEANING	19.3934	15	0.2204	30	14.6395	5
5	GARDENING	3.1791	29	2.3037	17	1.5625	21
6	PET CARE	2.4793	32	2.8589	14	1.2679	25
7	CLOTHING AND LINENS	29.5275	12	4.8674	7	0.6897	28
8	HOUSE	47.6747	6	13.1595	2	0.3527	32
9	MEDICAL CARE GIVEN	1.8567	33	11.4465	3	0.3490	33
10	CHILD CARE	13.5624	17	0.7725	26	4.2962	9
11	FINANCIAL MANAGEMENT	43.8282	8	3.7138	8	1.0337	27
12	TRAVEL/PRO MEDICAL	0.9916	36	5.9976	6	0.6737	29
13	TRAVEL/EDUCATION	0.7696	37	2.7897	15	1.5984	19
14	TRAVEL/ORG & RELIGION	3.6480	27	3.2184	11	1.3232	23
15	TRAVEL/SOCAL LIFE	10.8161	19	3.2043	12	1.3402	22
16	TRAVEL/LEISURE	1.3563	34	3.2329	10	1.3210	24
17	SHOPPING/NON-TRADABLE	8.1857	23	1.8148	22	2.2126	14
	TOTAL--TRADABLE	524.3245		1.3497		3.2310	
18	PERSONAL CARE @HOME	45.5239	7	0.1225	32	33.3256	3
19	PERSONAL CARE SERVICES	2.8483	31	7.3909	4	0.5126	30
20	MED CARE RECEIVE @HOME	0.1939	38	0.0000	--	-----	--
21	PRO MEDICAL CARE	8.6097	22	38.9626	1	0.1018	34
22	EATING AT HOME	40.4913	11	0.0000	--	-----	--
23	EATING OUT	28.4459	13	2.1383	19	2.1808	15
24	SLEEP AND REST	356.7312	1	0.0000	--	-----	--
25	VACATION	23.4402	14	1.9482	21	2.2278	13
26	EDUCATION	12.2890	18	2.1793	18	2.1279	16
27	RELIGION	9.8360	21	2.3307	16	1.6818	18
28	OTHER ORGANIZATIONS	2.9431	30	7.1988	5	0.3941	31
29	TELEVISION	51.1905	5	0.0825	34	54.9496	1
30	READING	40.6239	10	0.1097	33	40.7793	2
31	SOCIAL LIFE	61.1685	3	1.0325	24	4.1640	11
32	CONVERSATION	16.3143	16	0.7607	28	5.1222	8
33	OUTDOORS	10.4861	20	3.1674	13	1.5952	20
34	ENTERTAINENT	5.8550	26	0.8079	25	4.1939	10
35	LISTENING TO SOUNDS	7.7920	24	0.7685	27	6.2868	7
36	PERFORMING	1.3051	35	3.4485	9	1.2247	26
37	HOBBIES AND CRAFTS	6.7593	25	0.4832	29	7.6854	6
38	PERSONAL LETTERS	3.5822	28	0.1826	31	20.1299	4
	TOTAL	1260.7563		0.7465		5.8138	

ASSUMPTIONS ABOUT THE THE OVER $20,000 HOUSEHOLD INCOME CLASS

	WAGE RATE ($/HOUR AFTER TAX)	POPULATION (MILLIONS)
EMPLOYED MEN	5.69	14 33
EMPLOYED WOMEN	3.13	8.95
HOUSEWIVES	2.64	5.01

TOTAL NUMBER OF HOUSEHOLDS 10.12 MILLION

VALUE OF TIME VS. MARKET EXPENDITURES FOR ALL HOUSEHOLDS

	ACTIVITY	MINUTES/DAY EMPLOYED MEN	MINUTES/DAY EMPLOYED WOMEN	MINUTES/DAY HOUSE-WIVES	1973 $/HOUSE-HOLD MARKET EXPEND-ITURES	BILLION 1973 $ EMPLOYED MEN VALUE OF TIME	BILLION 1973 $ EMPLOYED WOMEN VALUE OF TIME	BILLION 1973 $ HOUSE-WIVES VALUE OF TIME	BILLION 1973 $ TOTAL VALUE OF TIME	BILLION 1973 $ TOTAL MARKET EXPEND-ITURES	PERSON HOURS (MIL-LIONS)
1	JOB	391.80	298.28	3.98	0.0	525.90	143.09	4.07	673.05	0.00	183565.8
2	TRAVEL TO JOB	40.69	28.31	0.43	565.5	59.13	14.29	0.45	73.87	40.27	18541.5
3	FOOD PREPARATION	24.51	86.84	155.56	1360.9	34.08	39.45	95.22	168.75	96.91	58214.8
4	HOUSE CLEANING	7.48	42.41	77.17	56.5	10.46	20.92	46.34	77.73	4.02	27268.5
5	GARDENING	1.67	1.88	3.60	54.9	2.03	1.40	1.88	5.31	3.91	1669.9
6	PET CARE	1.23	1.38	2.56	65.9	1.52	1.00	1.34	3.86	4.69	1208.2
7	CLOTHING AND LINENS	7.57	33.92	66.17	862.8	9.96	13.67	37.99	61.61	61.44	23264.4
8	HOUSE	15.45	6.84	11.82	2032.1	24.04	3.28	6.95	34.28	144.71	8767.5
9	MEDICAL CARE GIVEN	0.59	0.62	0.95	83.0	0.81	0.30	0.56	1.67	5.91	514.0
10	CHILD CARE	8.34	21.92	74.05	144.4	10.68	9.58	46.90	67.16	10.28	22828.0
11	FINANCIAL MANAGEMENT	20.27	31.96	40.36	914.6	28.59	14.21	22.80	65.60	65.13	21361.9
12	TRAVEL/PRO MEDICAL	0.49	0.50	0.57	31.9	0.70	0.25	0.34	1.29	2.27	375.3
13	TRAVEL/EDUCATION	0.75	0.40	0.75	16.0	1.02	0.18	0.43	1.63	1.14	476.9
14	TRAVEL/ORG & RELIGION	3.02	2.38	3.73	84.7	4.08	1.09	2.17	7.33	6.03	2224.2
15	TRAVEL/SOCAL LIFE	9.06	7.94	9.70	249.2	12.23	3.63	5.63	21.49	17.75	6509.7
16	TRAVEL/LEISURE	1.51	1.59	1.49	43.1	2.04	0.73	0.87	3.63	3.07	1110.6
17	SHOPPING/NON-TRADABLE	6.96	8.02	9.23	137.4	9.59	3.94	5.47	19.00	9.78	5761.4
	TOTAL--TRADABLE	541.39	575.21	462.12	6702.9	736.85	271.00	279.41	1287.26	477.31	383663.4
18	PERSONAL CARE @HOME	55.31	71.77	67.42	79.1	73.33	32.59	38.83	144.75	5.63	46090.3
19	PERSONAL CARE SERVICES	0.97	1.94	1.95	92.9	1.29	0.88	1.13	3.29	6.61	1108.2
20	MED CARE RECEIVE @HOME	0.24	0.24	0.49	0.0	0.32	0.11	0.28	0.71	0.00	229.2
21	PRO MEDICAL CARE	0.97	0.97	1.95	473.3	1.29	0.44	1.13	2.85	33.71	916.8
22	EATING AT HOME	56.34	46.66	70.05	0.0	77.25	23.36	39.53	140.15	0.00	42025.7
23	EATING OUT	31.63	23.33	5.92	441.1	43.37	11.68	3.34	58.39	31.41	15870.8
24	SLEEP AND REST	461.86	470.79	481.47	0.0	636.30	218.92	300.47	1155.69	0.00	342062.4
25	VACATION	23.77	23.73	23.77	262.7	32.93	11.28	14.46	58.67	18.71	17290.3
26	EDUCATION	8.74	5.06	5.11	105.5	12.43	2.05	2.82	17.30	7.52	4854.3
27	RELIGION	7.04	8.90	14.39	156.3	8.04	3.74	8.14	19.92	11.13	7065.5
28	OTHER ORGANIZATIONS	5.33	3.05	10.43	58.0	5.75	0.80	5.18	11.74	4.13	4521.1
29	TELEVISION	96.27	61.92	95.13	62.3	117.84	25.76	64.18	207.78	4.44	63031.3
30	READING	37.79	26.08	36.52	47.7	61.41	14.83	20.01	96.25	3.40	24917.8
31	SOCIAL LIFE	61.01	65.01	89.69	541.0	81.62	27.76	57.70	167.09	38.52	51332.4
32	CONVERSATION	12.91	17.82	30.09	178.0	18.34	9.08	18.39	45.81	12.68	14043.6
33	OUTDOORS	12.46	5.27	4.56	143.8	18.35	3.29	2.53	24.17	10.24	5956.1
34	ENTERTAINENT	11.07	10.84	6.29	49.2	16.42	5.72	3.56	25.71	3.50	6985.1
35	LISTENING TO SOUNDS	5.85	5.25	3.12	58.7	9.36	2.94	1.99	14.29	4.18	3554.8
36	PERFORMING	0.95	0.49	2.00	18.6	1.43	0.26	1.07	2.76	1.32	827.0
37	HOBBIES AND CRAFTS	5.24	9.80	17.52	32.9	7.87	5.17	9.36	22.40	2.34	7344.2
38	PERSONAL LETTERS	2.86	5.88	10.01	9.5	4.29	3.10	5.35	12.74	0.68	4208.9
	TOTAL	1440.00	1440.00	1440.00	9513.6	1966.09	674.78	878.85	3519.73	677.46	1047898.4

CONTINUATION OF VALUE OF TIME VS. MARKET EXPENDITURES FOR ALL HOUSEHOLDS

		TOTAL EXPENSE BILLION $	RANK	MARKET EXPENDITURES PER HOUR	RANK	RATIO TIME VALUE/ MARKET EXPENDITURES	RANK
1	JOB	673.0488	2	0.0000	--	-----	--
2	TRAVEL TO JOB	114.1355	11	2.1717	14	1.8345	19
3	FOOD PREPARATION	265.6624	3	1.6647	18	1.7413	21
4	HOUSE CLEANING	81.7571	14	0.1476	31	19.3143	4
5	GARDENING	9.2173	31	2.3410	13	1.3578	23
6	PET CARE	8.5521	32	3.8851	6	0.8219	29
7	CLOTHING AND LINENS	123.0567	10	2.6410	11	1.0028	28
8	HOUSE	178.9853	6	16.5050	2	0.2369	33
9	MEDICAL CARE GIVEN	7.5795	33	11.4954	3	0.2828	32
10	CHILD CARE	77.4410	15	0.4504	28	6.5317	8
11	FINANCIAL MANAGEMENT	130.7249	9	3.0488	7	1.0072	27
12	TRAVEL/PRO MEDICAL	3.5617	36	6.0607	4	0.5657	30
13	TRAVEL/EDUCATION	2.7715	37	2.3850	12	1.4367	22
14	TRAVEL/ORG & RELIGION	13.3613	29	2.7105	10	1.2163	24
15	TRAVEL/SOCAL LIFE	39.2392	18	2.7259	9	1.2113	25
16	TRAVEL/LEISURE	6.7021	34	2.7652	8	1.1824	26
17	SHOPPING/NON-TRADABLE	28.7811	23	1.6980	17	1.9420	17
	TOTAL--TRADABLE	1764.5752		1.2441		2.6969	
18	PERSONAL CARE @HOME	150.3827	7	0.1222	33	25.7043	3
19	PERSONAL CARE SERVICES	9.9050	30	5.9665	5	0.4980	31
20	MED CARE RECEIVE @HOME	0.7131	38	0.0000	--	-----	--
21	PRO MEDICAL CARE	36.5594	19	36.7666	1	0.0846	34
22	EATING AT HOME	140.1457	8	0.0000	--	-----	--
23	EATING OUT	89.8035	13	1.9792	15	1.8590	18
24	SLEEP AND REST	1155.6926	1	0.0000	--	-----	--
25	VACATION	77.3771	16	1.0821	23	3.135[illegible]	12
26	EDUCATION	24.8189	24	1.5481	21	2.3025	15
27	RELIGION	31.0529	21	1.5754	20	1.7898	20
28	OTHER ORGANIZATIONS	15.8654	27	0.9135	24	2.8415	13
29	TELEVISION	212.2163	4	0.0704	34	46.8288	1
30	READING	99.6497	12	0.1364	32	28.3208	2
31	SOCIAL LIFE	205.6097	5	0.7505	26	4.3373	9
32	CONVERSATION	58.4837	17	0.9028	25	3.6128	10
33	OUTDOORS	34.4161	20	1.7197	16	2.3600	14
34	ENTERTAINENT	29.2116	22	0.5015	27	7.3383	7
35	LISTENING TO SOUNDS	18.4763	26	1.1764	22	3.4181	11
36	PERFORMING	4.0799	35	1.5975	19	2.0882	16
37	HOBBIES AND CRAFTS	24.7392	25	0.3188	29	9.5678	6
38	PERSONAL LETTERS	13.4218	28	0.1614	30	18.7553	5
	TOTAL	4197.1875		0.6465		5.1954	

ASSUMPTIONS ABOUT THE ALL HOUSEHOLDS

	WAGE RATE ($/HOUR AFTER TAX)	POPULATION (MILLIONS)
EMPLOYED MEN	3.80	51.96
EMPLOYED WOMEN	2.09	32.44
HOUSEWIVES	2.85	35.22

TOTAL NUMBER OF HOUSEHOLDS 71.21 MILLION

LEGAL RESTRAINTS CONFRONTING DOMESTIC U.S. FIRMS IN THEIR FOREIGN OPERATIONS

Lindsay Bower
February 1979

Abstract

This paper deals with issues arising in regard to United States laws and regulations which apply to domestic firms doing business abroad. It also is concerned with the general nature of restrictions and incentives that foreign governments (sometimes referred to as "host governments") impose upon, or offer to, such firms. Foreign law is far from uniform, though, so detailed analyses of the problems that U.S. firms might encounter from host governments are presented only on a case-by-case basis.

The various legal issues that are examined here can be categorized into two types: those relating to export sales and those associated with foreign subsidiary operations. United States firms sell their products abroad in both of these ways, but the law governing export sales differs markedly from the regulation of foreign subsidiaries. Because U.S. industries that might expand international sales would probably be technological and because other governments tend to be protective of such industries, it is assumed that most of the growth in U.S. international trade would be earned by foreign subsidiaries of domestic corporations. For that reason, most of this paper is concerned with the incentives and restrictions faced by such "multinational enterprises."

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PROGRAM IN INFORMATION POLICY

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This paper deals with issues arising in regard to United States laws and regulations which apply to domestic firms doing business abroad. It is also concerned with the general nature of restrictions and incentives that foreign governments (sometimes referred to below as "host governments") impose upon, or offer to, such firms. Foreign law is far from uniform, though, so detailed analyses of the problems that U.S. firms might encounter from host governments are presented only on a case-by-case basis.

It appears that the various legal issues that are examined here can be analyzed most conveniently by categorizing them into two separate types of problems: those relating to export sales and those associated with foreign subsidiary operations. United States firms operating abroad make extensive sales through both types of transactions[1] and the law governing export sales differs markedly from the regulation of foreign subsidiaries. Furthermore, because U.S. industries that might be expected to expand their sales in international markets would probably be very technological in nature and because governments tend to be highly protective of such industries,[2] it is assumed that most of the growth in U.S. international trade that might result from such an expansion would be earned by foreign subsidiaries of domestic corporations. For that reason, most of this paper is concerned with the incentives and restrictions faced by such "multinational enterprises" (MNE's).

II. <u>The Legal Limitations and Advantages of Operating Through Foreign Subsidiaries</u>

Doing business through a foreign subsidiary presents a wide spectrum of issues for any United States-based company. MNE's are heavily regulated by both foreign and domestic statutes. Many financial and political considerations are also apt to arise in connection with an MNE's international dealings.

Experts in international affairs seem to have reached a rough consensus on the question of which United States laws have the greatest impact on the operations of MNE's. Without question, the two most important are the Internal Revenue Code and the Sherman Act.[3] Other statutes frequently cited by authorities on international business are the Trading With The Enemy Act, and certain investment guaranty statutes.[4]

Unfortunately, it is extremely difficult, if not impossible, to provide any clear guidance with respect to the meaning of the first three of those acts. The antitrust and tax laws relating to MNE's are extremely complicated and rapidly changing. Likewise, last year, an important change was made in the Trading With The Enemy Act which could have significant, although as yet unknown, effects on future operations of MNE's.

A. <u>The Antitrust Laws</u>

Of the three areas of law mentioned above, the Sherman Act's regulation of MNE's seems to be both the most complicated and the most confusing.[5] Foreign antitrust law is complicated because antitrust law itself is complicated. However, the law is confusing for a number of reasons. First, the courts have been unable to agree upon the underlying purpose of the

antitrust laws. Some courts claim that the purpose is to promote consumer welfare, while others argue that the laws were enacted to protect "competition." As will be shown below, this difference of opinion has had important implications for foreign antitrust law. A second source of confusion has been the careless attitude that courts have taken in writing opinions involving foreign antitrust issues. Section 1 and Section 2 questions are frequently treated together; and when they are examined separately, the standard of analysis has been poor. The final source of confusion has been the relatively small number of foreign antitrust cases decided. Hundreds, perhaps thousands, of domestic antitrust cases are tried or settled every year; but the total number of foreign antitrust opinions appears to be approximately three hundred.[6] As a result, the body of foreign antitrust law has been unable to quickly incorporate changes in domestic antitrust rules.

Not surprisingly, this confusion has had adverse effects on foreign investment by U.S. corporations. Seventy percent of a group of companies surveyed claimed that the antitrust laws had injured their ability to compete in international markets.[7] Of course, not all of that injury was due to the confused state of the law. However, a substantial portion can be attributed to that source. "Uncertainty as to what is and what is not legal often forces business decision-makers to turn down profitable ventures in order to avoid costly and time-consuming court determinations."[8]

It should also be noted that a business considering an overseas investment has no means of obtaining a guarantee that its actions will not violate the antitrust laws. Federal courts cannot provide such

assurance because, under the Constitution, they are empowered to provide judgments only with respect to "case(s) or controver(sies)." Thus, the courts may not render judgments with respect to hypothetical disputes that may occur in the future (except in the narrow cases where declaratory judgments are warranted). Likewise, the Justice Department has no power to grant immunity to businesses from either governmental or private antitrust suites.[8.5]

Several questions relating to foreign antitrust law are of importance to MNE's doing business in international markets. The most important of these questions is "subject-matter jurisdiction": the issue of which types of foreign activities can be examined under the Sherman Act by a United States court. MNE's must also be aware of the question of when a United States corporation and one of its foreign subsidiaries can be found liable under Section 1 for conspiracy in restraint of trade. Finally, because foreign subsidiaries of telecommunication-related MNE's may possess technology that is superior to that of their local competitors, it is important to examine the circumstances under which such a subsidiary can be held liable for monopolization or attempted monopolization of a foreign market.

1. Jurisdictional issues

a. Such issues are important because, if analyzed correctly, they may provide MNE's with the means of avoiding the restrictions imposed by the United States antitrust laws.

b. Subject Matter Jurisdiction

1) Established when it is shown that a defendant's alleged restraint of trade had certain types of effects on "trade or commerce... with foreign nations."

2) Courts have used a variety of tests to determine whether those requisite effects existed. Four primary criteria:

(a) "Direct and Substantial" effects;

(b) "Not indirect and not insubstantial" effects;

(c) The alleged restraint must be either "in" or substantially affecting the course of commerce;

(d) The Timberlane test.

3) Until recently, a finding of jurisdiction was basically a foregone conclusion.[9]

4) More recently, though, there have been some indications that jurisdiction will be found in foreign antitrust cases only where there is proof of an adverse effect upon U.S. commerce.

a) There is no direct authority for that proposition.

b) However, the Justice Department takes the view that, in foreign markets, the purpose of the antitrust laws is "to protect individual firms from bully-boy tactics by their more powerful competitors."[10]

c) That view is based upon outdated Supreme Court decisions. The Court's recent Sylvania v. Continental T.V. ruling clearly held that the Sherman Act's goal is the protection of the consuming public and not that of a defendant's competitors.[11]

d) On the basis of that decision, it could be argued that Sherman Act jurisdiction may be applied to anti-competitive acts

which take place abroad only if an adverse effect upon the interests of the American public is shown.

5) If adopted, such a rule would have major implications for MNE's investment decisions since most of their foreign operations would probably be viewed as having insubstantial effects upon the interests of U.S. consumers. It would be difficult to argue that an overseas subsidiary which does not possess significant power in some domestic market could significantly affect the economic well-being of the American public. In fact, if the Sylvania ruling were extended to foreign antitrust law, the only situations where the acts of an overseas subsidiary would apparently be affected by the antitrust laws would be where that firm purchased or sold a substantial share of the output of some U.S. market. Those situations are probably rare, however, so the Sylvania ruling could be expected to free foreign subsidiaries of most of the restraints imposed by the Sherman Act.

c. The Act of State Doctrine[11a]

1) When applied, courts will refuse to invoke jurisdiction: The doctrine as formulated in past decisions expresses the strong sense of the Judicial Branch that its engagement in the task of passing on the validity of foreign acts of state may hinder rather than further this country's pursuit of goals both for itself and for the community of nations as a whole in the international sphere.[12]

2) Significance for MNE's doing business in telecommunications-related international markets: such markets tend to be either totally controlled or else heavily regulated by national governments. Consequently, acts of MNE's operating in those markets may essentially be those of the foreign states and therefore immune from prosecution under the Sherman Act.

3) Circumstances under which the Act of State Doctrine will be applied:

a) In general, courts will apply the Act of State doctrine where the circumstances are such that invoking jurisdiction would create a strong potential for interference with our foreign relations.[13]

b) And, in foreign antitrust suits, the question of whether such a potential will be found seems to depend on how important the foreign state views the actions which are complained of. If the state was not aware of the action in question, it will be presumed that the foreign government attached little importance to the defendant's alleged restraint of trade. However, if a foreign subsidiary was compelled to act in a certain, otherwise illegal manner, the Act of State doctrine will be applied. The crucial and most disputed and controversial question is whether jurisdiction will be invoked where the foreign state permits, condones, or encourages the action in question.

(1) Lack of governmental knowledge: Continental Ore v. United States[14] - There, Canada made a Canadian subsidiary of the defendant its wartime agent for the purchase of vanadium. The parent and subsidiary then used that power to exclude the plaintiff from the Canadian market for that metal. The Supreme Court refused to invoke the Act of State doctrine because there was no indication that any Canadian official "approved or would have approved" the defendant's monopolization efforts.[15]

(2) Government compulsion: Intraamerican Refining Corporation v. Texaco Maracaibo, Inc. - In that case, the defendant was compelled by the Venezualan government to refuse to sell Venezualan crude oil to the plaintiff. The court held:

"When a nation compels a trade practice, firms there have no choice but to obey. Acts of business become effectively acts of the sovereign."[17]

(a) A possible exception to the compulsion rule: "inducement of compulsion." Cases decided before 1970 generally held that the Act of State doctrine was inapplicable where a defendant was compelled by a foreign sovereign to perform allegedly anticompetitive acts and where that compulsion was "induced" by the defendant.[18]

However, the most recent case involving that issue, Occidental Petroleum Corp. v. Buttes Gas & Oil Co.,[19] came to an opposite conclusion. There, to obtain oil exploration rights in certain offshore regions, the defendant induced several foreign governments to alter their territorial water claims over those regions. As a result of these altered claims, plaintiff was prevented from exploring for oil in those same regions. Nonetheless, the court found the Act of State doctrine to be a complete defense to the plaintiff's antitrust action.

Thus, the courts may now be taking the view that foreign states can best judge for themselves whether or not they will take a particular action, even if that action has been induced by a U.S. company and has had adverse effects on other U.S. businesses. Such a trend would undoubtedly be welcomed by MNE's. The inducement exception to the Act of State doctrine appears to be paternalistic and excessively ambiguous. Furthermore, it places an almost impossible burden on U.S. corporations which have dealings with foreign states. Under the pre-Occidental rule, such firms were required to somehow ensure that they did not "induce," as opposed to negotiate, benefits from foreign states, whenever those benefits might work contrary to the interests of competitive firms.

(3) Acquiescence or approval of a foreign government - Until recently, the courts seemed to take the position that if a foreign state only condoned or approved a questionably anticompetitive activity, the activity was not of sufficient importance to that government to permit the invocation of the Act of State doctrine. Thus, in United States v. Watchmakers of Switzerland Information Center, Inc.,[20] the United States government brought suit against a group of Swiss watch manufacturers and sellers who had entered into a private agreement in Switzerland. The agreement allegedly had anticompetitive effects on U.S. commerce, but the Swiss government passed legislation which was designed to aid the enforceability of the contract. Nonetheless, because the legislation did not require the defendants to act in a prescribed manner, they were found liable for violation of the Sherman Act.

The Swiss Watchmakers decision has been heavily criticized,[20] but it is the most recent decision to confront the issue of foreign government acquiescence or approval. As a result, few conclusions can be drawn in that area of law, and MNE's certainly cannot assume that anything less than governmental compulsion will immunize them from the reach of the United States antitrust laws.

(4) Conclusion. The Act of State doctrine is of key importance in determining the antitrust implications of MNE's doing business in telecommunications-related markets. Although there is a great deal of uncertainty as to when it will be invoked, the doctrine is clearly applicable in cases of governmental compulsion and it may be applicable when such compulsion is induced by the defendent. In contrast, where the "compelling government" lacks knowledge of the defendant's

illegal acts, no antitrust immunity is granted. However, where the host government only acquieses or approves of the defendant's action without compelling them, the law is unclear. Traditionally, such acquiescense has provided no immunity from the antitrust laws, but no court has specifically addressed the acquiescense issue in over twenty years and, in that interim, the standing rules have come under attack.

2. Bathtub Conspiracies and the MNE

a. Development of the Bathtub Conspiracy theory: Section 1 forbids conspiracies or combinations in restraint of trade. Furthermore, under the antitrust laws, a corporation and its incorporated subsidiaries are viewed under certain circumstances as independent entities. Consequently, some courts have concluded that Section 1 can be violated when a coporation and its incorporated foreign subsidiaries collaborate in such decisions as product pricing or areas of sales responsibility.

b. The law of intra-enterprise conspiracy:

1) In general, there are three major types of conduct which will warrant the application of Section 1 to intra-enterprise conspiracy.

a) Situations where affiliates hold themselves out as competitors.[21] Thus, in the leading Kiefer-Stewart case,[22] the defendant distilleries and their sales organizations were found liable for conspiracy to sell only to those wholesalers who would sell at or below maximum prices set by defendants. Defendants argued that as "mere instrumentalities of a single manufacturing-merchandizing unit," they were incapable of conspiracy. However, the court rejected that argument and emphasized that common ownership does not remove the impact of the antitrust laws.[25]

b) Abuses of the Subsidiary Structure. This limitation is applied in instances where the subsidiary structure is selected specifically for achieving an anti-competitive result. For example, in U.S. v. Yellow Cab,[25] the Supreme Court found that the defendants conspired to monopolize the sale of cars to major cab companies by buying many such companies and then forcing the subsidiaries to purchase cabs from the parent corporation.

c) Internal decisions made by parent and subsidiary which have an impact on outsiders. In the In re Penn Central Litigation,[26] plaintiffs brought suit on the basis that defendant Pennco had conspired with its subsidiaries to divide markets and to thereby injure certain minority shareholders. Not surprisingly, the court held that such decisions were outside the scope of Section 1.

2) Under current law, only the competitor limitation may still be applicable. Commentators have attacked all extensions of the intra-enterprise doctrine beyond the first two theories mentioned above.[27] And, in a recent case, the Supreme Court indicated in dictum that the doctrine may be relevant only in situations where parents and subsidiaries hold themselves out as competitors.[28]

c. Implications of the Bathtub Conspiracy Doctrine for MNE's

1) The Timken case. In Timken Roller Bearing Co. v. U.S., an MNE was found liable under Section 1 for conspiracy with its affiliates to divide world markets. Liability appeared to rest on two factors: 1) the affiliates always behaved as competitors; 2) formal market sharing agreements were entered into by the various Timken companies, indicating that the affiliates were not jointly owned and that they were, in fact, conspiring.

2) No other similar case has been brought against an MNE. This surprising lack of litigation is probably due to the ease with which MNE's can comply with Timken. Compared with other foreign antitrust decisions, the meaning of Timken is easily understood and the means of complying with the decision are relatively straightforward (i.e., by not indicating that offiliates are competitors and by not entering into formal, anticompetitive agreements).

3) Possible restraints that Section 1 may impose on an MNE's international operations. Under that statute, MNE parents may be forbidden from directing subsidiaries with respect to:

a) what markets the affiliate may sell in;

b) combining sales efforts;

c) allocating customers or products;

d) exchanging price or cost information.[30]

3. Section 2 and the MNE

a. Difficulty of making any judgments with respect to monopolization or attempted monopolization of foreign markets.

1) All but a very small number of foreign antitrust cases containing Section 2 issues seem to involve issues of monopolization of supply of some product to the U.S.

2) In the few cases which are relevant to MNE's, Section 1 and Section 2 issues are usually hopelessly intertwined.

3) There has been no Section 2 case involving restraints of foreign markets in over fifteen years.

b. General nature of Section 2 claims. To establish either monopolization or attempted monopolization, a plaintiff must first define the geographic and product markets that have been allegedly restrained. Then, if monopolization is charged, the defendant must be shown to control a substantial portion of the relevant market (usually at least 50 percent). If the issue is attempted monopolization, the plaintiff must prove that the defendant had a specific intent to monopolize the market in question; and that, although the defendant's attempt failed, he had a strong probability of success. In either case, the market delineation is a crucial step.

c. Market definition in Foreign Antitrust Suits

1) Although the issue has never been directly addressed in the past, at some point the courts will have to determine the nature of the relevant geographic market in foreign antitrust suits. There are a number of possibilities:

a) The entirety of all foreign markets. Under this definition, a defendant would have to restrain worldwide trade, excluding the U.S., before liability would be found.[31]

b) The sum of the U.S. and all foreign markets. It can be argued that there is no reason to distinguish between U.S. and foreign buyers from the perspective of the Sherman Act.[32]

c) Particular, isolated foreign markets.[33]

d. The applicable standard.

1) Unfortunately, there is only one antitrust decision which provides any meaningful guidance to the applicable standards governing

Section 2 violations; and, that case, Continental Ore Co. v. Union Carbide & Carbon Corp.,[34] was decided fifteen years ago. Moreover, it failed to explicitly discuss the all-important question of relevant geographic market. In Continental, it was alleged that the defendants used various anticompetitive methods to exclude the plaintiff from vanadium markets in Canada. A lower court held for the defendants, but the Supreme Court reversed. In doing so, the Court made no attempt to define the relevant market. Instead, the court based its decision on a finding of proof that the plaintiff was injured by the defendants' actions.

2) Thus, on the basis of the Continental holding, it would appear that a Section 2 violation can be found if an overseas business has taken steps to exclude a U.S. competitor from any overseas market and if that competitor has been injured by its exclusion.

d) Conclusion. The importance and meaning of Section 2 to MNE's is unclear. The fact that there have been very few foreign antitrust decisions involving Section 2 issues indicates that monopolization or attempted monopolization of a foreign market may be difficult to prove. However, the ambiguity of those cases that have been decided indicates that the monopolization of any foreign market, no matter how small and no matter where it is located, is a risky course of action. Under current law, such monopolization or attempted monopolization may violate Section 2 if another American firm is in any way excluded from the market. However, because monopolization of foreign markets does not appear to affect the economic interest of American consumers and because the courts may in the future require proof of that type of effect in

foreign antitrust suits, Section 2 may soon have little effect on decisions made by MNE's with respect to their foreign operations.

B. The Internal Revenue Code

An MNE subsidiary with operations in a foreign country may have a choice of being incorporated in the U.S. or abroad. Both alternatives have certain tax advantages. However, many foreign governments either require, or provide strong incentive for, local incorporation. Consequently, I have devoted most of my tax-related research to the issue of tax advantages of foreign incorporation.

1. Advantages under the Internal Revenue Code (IRC) of Foreign Incorporation.

a. Deferral

1) Under Sec. 882 of the IRC, a foreign corporation is taxed only on income derived from sources within the U.S. This results in deferral of tax on most of the foreign source income of a foreign corporation owned by a U.S. company until they actually receive dividends.[35]

2) Consequences of Deferral.

a) Deferral has no effect on decisions that are made with respect to investing capital in developed countries that have tax rates as high as or higher than those of the U.S. (e.g., Canada, Japan, and many common market countries), since taxes paid to such governments can be credited against U.S. tax obligations.[36]

b) Subject to the restrictions of subpart F, profits from foreign obligations can be reinvested in other profitable, foreign ventures without being taxed by the U.S.[37]

c) Tax Havens. Under certain circumstances, an MNE with operations in several foreign countries will establish a holding company or "base company" into which the profits from the various affiliates can be collected. The base company is usually incorporated in a nation which has a low tax burden, such as Switzerland or Bermuda.[38] The advantages of such a mechanism have been described as follows:

> The multinational corporation, with income sources from many nations, each with varying tax rates, can reduce its tax liability by pooling group profits in the area of lowest taxation. The wisdom of this activity from the standpoint of profit maximization is apparent. For instance, suppose a multinational parent corporation has its headquarters in the United States but subsidiaries in several foreign countries. If the profits of those subsidiaries are remitted directly to the parent corporation, they are taxed at the United States rate of 48 percent. But if these same profits are remitted to a Swiss base company, at no more than the maximum Swiss rate of 30-40 percent and usually at a much lower rate. The result is that a considerable tax saving is achieved. Earnings which would have otherwise been lost as taxes are then held by the Swiss base company Of course, these profits kept in Switzerland are unavailable as dividends to the multinational's parent corporation in the United States. However, this pool of capital concentrated in Switzerland is available for new profitable undertakings among the multinational group.[39]

Thus, through the use of a "tax haven," an MNE can pool its group profits, reduce its overall tax burden, and use the pooled income for further ventures before the earnings are repatriated.

3) Current and Proposed Limitations on Tax Deferral.

a) Subpart F of the IRC. (IRC Secs. 951-964). Subpart F was enacted in 1962 to restrict the use of tax avoidance schemes such as tax havens.[40] Under that provision, any United States shareholder who owns greater than 10 percent of a foreign corporation must declare as income his portion of the undistributed "foreign base company earnings" of that corporation.[41] However, such foreign base company income does not include income derived from the manufacture, production, or sale of property in the foreign corporation's country of incorporation.[42]

b) Possible Repeal of the Deferral Option. The availability of the deferral option to MNE's has been heavily criticized, primarily because it provides MNE's with an incentive to establish manufacturing operations in foreign countries with low effective tax rates.[43] Although strong arguments can be raised for the retention of the current deferral provisions, there appears to be strong support for altering the tax code in such a way as to reduce those incentives.[44]

b. Tax Credits.

1) Description. Under IRS Sec. 902, a domestic corporation owning at least 10 percent of a foreign corporation is given a tax credit for certain types of taxes that are paid by the subsidiary to foreign states.

2) Limitations.

a) Not all foreign taxes are creditable. For example, the value-added tax, a major source of revenue for many European countries,

is not creditable.[45] IRC Sec. 902 applies only to "income, war profits, and excess profits taxes;[46] and the government appears to have construed that provision strictly.[47]

b) Possible Repeal. Repeal or modification of the foreign tax credit has been proposed on the grounds that state taxes are allowed only as a deduction from federal taxes and that (the argument continues) the IRC should treat foreign and state taxes in a similar fashion. Although the arguments in favor of that position are weak, its proponents appear to have strong support.[48]

2. Tax Advantages to an MNE of U.S. Incorporation. I have not researched this issue in detail. Some of the strongest advantages appear to be:

(a) The investment credit and the Asset Depreciation Range (ADR) system are available only for property used predominantly in the United States.

(b) Only domestic corporations may be consolidated with a United States parent corporation, so foreign losses in a foreign subsidiary may not offset United States tax, nor may they be inherited upon liquidation of the foreign subsidiary.

(c) Dividend distributions of appreciated property made by a foreign subsidiary to its United States parent are taxed at fair market value, whereas similar distributions by a domestic subsidiary are taken into account only to the extent of the basis of the distributed property.

(d) The 85 percent dividends-received deduction is not allowed with respect to foreign subsidiary dividends.[49]

C. Export Controls

1. The Trading with the Enemy Act (50 App. 1).

a. Possibly the most controversial of all restraints that the U.S. imposes upon its MNE's.[50]

b. Under the associated regulations written by the Treasury Department, it is illegal to sell certain types of merchandise to "designated" countries.[51] The designated countries include most, if not all, of the countries controlled by the U.S.S.R. and Communist China.

c. Implication for MNE's. The controls of the Act "apply to 'any person' over whom the United States has jurisdiction. Since the boards of directors of many foreign subsidiaries of American corporations are composed in whole or part of American citizens, the potential scope of application of these controls is very wide. Conflict has resulted. The classic case was that of Fruehauf-France, a French subsidiary of an American company."[52] There, the U.S. government ordered the American parent to order its French subsidiary to rescind a contract with a French truck manufacturer. Under that contract, Fruehauf was obliged to supply parts for trucks that were to be sold to Red China.

d. Possible future change in the regulations. The current regulations were written under the authority of 50 App. 5(b), as that statute read before December 28, 1977. That version of Section 5(b) provided that "During any time of war or national emergency, the President may...investigate, regulate...transactions involving any property in which any foreign country...has any interest." (emphasis supplied) However, last year, Congress deleted the words "or national emergency" from

the statute. Consequently, because we are not now in a "time of war,"[53] it appears that the Treasury Department is no longer authorized to prohibit sales to designated countries.[54]

2. Export Administration Act. Under this provision, "licenses of different sorts are required for the export from the United States of technical data and commodities. Most such exports are made pursuant to 'general licenses,' which in effect permit the free export to most nations of most commodities. Some materials and data, mainly in the field of so-called strategic items, are more tightly controlled; and some nations are subject to restrictions of varying degrees of severity...(W)hen goods are exported to, say, Canada, the same restrictions are imposed for re-export as would be applicable for direct export from the United States."[55]

III. Limitations and Advantages of Export Sales

Firms which make international sales by exporting U.S. goods appear to be confronted with more restrictions than are firms which operate through foreign subsidiaries. Exporters must typically face both substantial tariff restrictions as well as nontariff barriers, such as quotas[56] and packaging and licensing laws.[57] Domestic impediments include a number of significant legal and financial restrictions. However, U.S. statutes also provide exporters with two legal advantages that MNE's do not possess.

The most important legal restriction imposed upon exporters appear to be those relating to documentation, cargo preferences, and health and safety laws.[58] In a 1968 study, the National Committee on International Trade Documentation found that documentation costs for all U.S. imports and exports totalled almost $6.5 billion per year, which amount was approximately 7.5 percent of the value of those shipments.[59] Similarly, cargo

preference, a type of indirect marine subsidy which requires that in certain cases U.S. goods be shipped in U.S.-flag vessels, also raises the cost of exporting.

Significant financial and economic factors include freight costs and the cost of export financing. One commentator has concluded that "governmental participation in export financing is probably the single most important element in a country's export-promotion efforts."[61] The United States' export financing agency, Eximbank, has announed that it "is determined that no U.S. exporter is going to lose a sale for want of credit."[62] However, it appears that the U.S.'s financing institutions are unable to effectively compete with those of Japan and the Common Market countries.[63] Freight rates on U.S. outbound ships, which are oftentimes higher than inbound rates, are also a deterrent to export sales.[64]

On the other hand, many exporters are able to take advantage of the immunity from the antitrust laws granted by the Webb-Pomerone Act and of certain special tax advantages. Under the Webb-Pomerone Act, competitors are allowed to form export trade associations which perform functions that would otherwise violate the antitrust laws.[66] Exporters may also organize Domestic International Sales Corporations (DISCs)[67] and Western Hemisphere Trade Corporations (WHTCs).[68] DISC corporations, which must make over 90 percent of their sales abroad and which must make those sales through exports, are permitted to defer taxation on up to 50 percent of their profits. Until 1979, WHTC corporations will be able to deduct up to 14 percent off their corporate income tax. However, after that year, that form of corporation will no longer enjoy any benefits under the IRC.

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1. In 1972, the value of U.S. exports exceeded $49 billion, Mullen, Export Promotion: Legal and Structural Limitations on a Broad United States Commitment, 7 Law & Policy In Int'l Business 57 at 83 (1975). United States direct investment abroad probably now approaches $100 billion, Stone, United Tax Policy Toward Foreign Earnings of Multinational Corporations 42 George Washington Law Review 557 (1974).

2. For example, in an attempt to bolster its domestic computer industries, Brazil recently put severe restrictions on the volume of foreign manufactured data processing equipment that can be sold in that country in the future. Following the announcement of those restrictions, several U.S. businesses applied for licenses to establish manufacturing subsidiaries in Brazil.

Computerworld, November 13, 1978.

3. National Association of Manufacturers, Taxes and International Business at 3 (1964).

4. See National Association of Manufacturers, supra, at 3.

5. Apart from Section 7, which governs mergers, this portion of the Clayton Act which might otherwise govern foreign subsidiaries only apply to sales and leases made within the United States, 15 U.S.C. 13(9), 14; Fugate, Foreign Commerce and the Antitrust Laws 19 (1973).

6. Fugate, International Antitrust Law Symposium, 8. J. Int. Law & Econ. 157 (1973).

7. National Association of Manufacturers, The International Implications of U.S. Antitrust Laws (1973) at iii.

8. National Association of Manufacturers, supra, at iii.
8.5 Panel Discussion, infra note 30, at 993.

9. Fugate, supra, note 6.

10. Baker, Antitrust and World Trade: Tempest in an International Teapot, 8 Cornell Int'l L. J. 16 at 22 (1974); Antitrust Division of the United State Dept. of Justice, Antitrust Guide for International Operators (1977).

11. Continental T.V., Inc. v. G.T.E. Sylvania Inc., 97 S.Ct. 2549 (1977).

11.a It should be noted that there are great differences of opinion among the courts and commentators concerning the question of whether Act of State is a jurisdiction question or a completely independent doctrine. See, Timberlane, supra; Intraamerican, infra; Simpson, infra.

12. Banco Nacional de Cuba v. Sabbatino, 376 U.S. 398 at 423 (1964). The classic statement of the doctrine may be found in Underhill v. Hernandez, 168 U.S. 250 at 252 (1897).

13. Timberland Lumber Co. v. Bank of America, 549 F.2d 597 at 607 (1976). This statement of the meaning of the doctrine is by no means universally accepted. In fact, every article written interprets that principle differently. For example, in Simpson, The Return of American B : A Contemporary Perspective on American Antitrust Abroad, 9 J. Intl' Law & Economics 233, the author reads Sabbatino as an application of choice of law concepts. However, for reasons too involved to be discussed here, I find the Timberland reading of Sabbatino to be the most persuasive.

14. 370 U.S. 690 (1962).

15. Continental Ore, supra, at 706.

16. 307 F. Supp. 1291 (1970).

17. Intraamerican, supra note 16, at 1298.

18. See Simpson, supra note 13, at 263.

19. 331 F. Supp. 92 (1971).

20. 1963 Trade Com. 70,600 (1962).

21. See, e.g. Simpson, supra note 13; Kinter and Hall Application United States Antitrust Laws on Trade and Commerce--Variations on American B since 1909, Boston College Industrial and Commercial Law Review 343, at 364-365.

21. Kiefer-Stewart Co. v. Joseph E. Seagram & Sons, 340 U.S. 211 (1951). See Willie and Pitofsky, Antitrust Consequences of Uisng Corporate Subsidiaries, 43 N.Y.U. L. Rev. 20, 36 (1968); Note, All In The Family. When Will Internal Discussions Be Labeled Intra-Enterprise Conspiracy, 14 Duquesne Law Rev. 63 at 69-77 (1975).

22. Kiefer-Stewart, supra note 21.

23. Kiefer-Stewart, supra note 21, at 215.

24. Id.

25. United States v. Yellow Cab, 332 U.S. 218 (1947). See also Willis and Pitofsky, supra note 21, Note, supra note 21, at 77-81.

26. 367 F. Supp. 1158 (1973).

27. See Willis and Pitofsky, supra note 21.

28. U.S. v. Citizens & Southern Nat'l Bank, 95 S. Ct. 2099.

29. 341 U.S. 593 (1951).

30. Panel Discussion, The Multinational Corporation 40 Antitrust Law Journal 992,995 (1975).

31. Brewster, Antitrust and American Business Aborad (1958).

32. Id.

33. Id.

34. 370 U.S. 690 (1962).

35. Jenks, Taxation of Foreign Income, 42 George Washington Law Rev. 537, 539 (1974).

36. Jenks, supra note 35, at 542.

37. Jenks, supra note 35, at 539.

38. Note, The Swiss Bank Company: Tax Avoidance Device for Multinationals 50 Notre Dame Law Rev. 645 (1975).

39. Note, supra note 38, at 645-646.

40. Jenks, supra note 35, at 543.

41. Jenks, supra note 35, at 544.

42. Jenks, supra note 35, at 544.

43. Jenks, supra note 35, 544-545.

44. Jenks, supra note 35, 544-548.

45. Decelles, How to Identify Creditable Foreign Taxes in Prentice-Hall, U.S. Taxation & International Operations, 5017.2.

46. IRC 3903 (b)(1)

47. Decelles, supra note 45.

48. Jenks, supra note 35, 549-553.

49. Jenks, supra note 35, 540-541.

50. Rubin, The Multinational Enterprise and the "Home" State in Ball, Global Companies: The Political Economy of World Business, 50-52.

51. 31 C.F.R. 505.

52. Rubin, supra note 50, at 52.

53. We are still in a state of national emergency, though. Veterans & Reserv. for Peace in Vietnam Com'r, 459 F. 2d 676 at 679 (1972).

54.

55. Rubin, supra note 50, 51.

56. Mullen, supra note 1, at 72-74.

57. Id.

58. Id. at 78.

59. Id. at 74-77.

60.

61. Id. at 84.

62. Id. at 87.

63. Id. at 104.

64. Id. at 77.

65. IRC 991-997.

66. IRC 921-922.